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Southwestern Kenya's smallholder dairy farmers' climate change perceptions, knowledge and adaptation

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Globally, climate change (CC) adaptation is critical as CC compounds smallholder dairy farmers' challenges. Farmers' CC perceptions and knowledge could influence their CC adaptations. This study in Southwestern Kenya sought to establish smallholder dairy farmers' CC perceptions and CC knowledge level and their relationships to CC adaptations. *Concurrent Fixed Mixed Methods* was used to collect data from 367 smallholder dairy farmers obtained by multi-stage sampling. Purposive sampling was used to pick qualitative study respondents. Binary logistic regression and *Framework* methods were used in data analysis. Meteorological data indicated an increase in both day and night temperature (0.3^{o}C) and mean annual rainfall (195 mm). Respondents perceived CC had high impact on dairy cattle health (61.0%) and feed availability (42.2%), and moderate effect on labour requirements (42.2%). Adaptation practices included mixed farming (96.5%), non-intensive production (95.1%), using household labour (94.6%), reducing herd size to 2 (92.9%), establishing own fodder (92.4%), rearing cross-bred cattle (87.7%), mainly of non-Friesian blood and their crosses (87.5), and maintaining an increasing trend in milk income (68.4%). Perceptions of decreased night temperatures significantly influenced mixed farming (Adjusted Odds=0.13; p=0.04) and rearing of non-Friesian breeds and their crosses (Adjusted Odds=0.19; p=0.01). Perceptions of no change in night temperatures significantly influenced rearing of non-Friesian breeds and their crosses (Adjusted Odds=0.08; p=0.02); and perceptions that distribution of short rains got worse significantly influenced adoption of own fodder (Adjusted Odds=0.02; p=0.01). Majority (61%) of respondents had above-average CC knowledge, with the total score greatly influencing dairy herd size (Adjusted Odds=0.11; p=0.02). Governments should invest in climate forecasting infrastructure and incorporate indigenous CC knowledge in CC adaption plans, strategies and policies.

Key words: Smallholder dairy farmers, climate change adaptation, Southwestern Kenya, perceptions, knowledge.

INTRODUCTION

Smallholder dairy systems are common in sub-Saharan Africa, and are rapidly experiencing expansion due to urban growth and the subsequent increasing demand for milk; hence, opportunities to generate income (Ojango et

al., 2017). Smallholder dairy farming in Kenya is practiced in mixed farming systems and contributes directly and indirectly to increased livestock population and farm productivity, income generation from milk and dairy product sales, job opportunities, and the transfer of money from urban to peri-urban and rural areas. Nevertheless, the system faces challenges of seasonality and less production, over-reliance on informal milk market, high feed costs (up to 50-60% of total production costs), and labour constraints (Otieno et al., 2021). There is also low level of investment by farmers to further improve the system, weak research-extension-farmer linkage, poor dairy infrastructure, and ever-diminishing land sizes due to land sub-division as population continues to grow (Ojango et al., 2017; Otieno et al., 2021), as well as high costs of artificial insemination (AI), poor access to breeding, animal health and credit services, inappropriate animal husbandry and farming practices (Otieno et al., 2021). Due to climate change, there is emergence of resistant strains of pests and diseases, and high pre- and post-harvest losses, leading to low financial returns on production (KAAA, 2016). It is for this matter that FAO recognizes 'smallholder farmers' on the basis of their limited resource endowments relative to other farmers in the sector, and that the definition differs between countries and between agro-ecological zones (Matekere, 2022).

A global trend observed in smallholder dairy production systems in most developing countries in recent decades due to climate change has been a significant change in patterns and quantities of rainfall; an increase in temperature; changes in winds; and changes in seasonality (ICARDA/CCAFS, 2012; Kirui, 2014). There has also been more frequent catastrophic events; a decrease in feed and fodder production; reduced water availability; changing patterns and distribution of diseases; and changes in the marketing and price of commodities (ICARDA/CCAFS, 2012; Ngare, 2017). Climate change in Africa has presented new challenges likely to erode much of the gains so far made with respect to food security, hampering rural development and livestock production (Ojango et al., 2016). Climate change will most likely lead to increased problems of water scarcity, shortage of pastureland and disease dynamics for smallholder dairy system (Tadesse and Dereje, 2018; Mashizha, 2019). These effects have forced most of the smallholder dairy farmers in several parts of the tropical world to resort to use of by-products or other wastes as feed, diversify production objectives to incorporate draught and meat production and increase levels of intensification (Ojango et al., 2017; WWF, 2023).

In Kenya, global warming and the associated climate change is expected to exacerbate the challenge smallholder dairy farmers face, as there will be declining pasture and feed varieties, as well as decreased natural water sources with diminishing water quality (KAAA, 2016). The effects are expected to get even worse if business as usual scenario is maintained (ICARDA/CCAFS, 2012; WWF, 2023), and would imply most of the Kenyan smallholder dairy farmers having challenges adapting and maintaining profitability (Hassan and Nhemachena, 2008; Tadesse and Dereje, 2018). To cope with these effects, the Kenyan smallholder dairy farmers make efforts to increase levels of intensification, but which contributes further to global warming (Hassan and Nhemachena, 2008).

Studies indicate that smallholder dairy farmers' perceptions of climatic changes taking place in their localities could influence how they would adapt to the effects (Banerjee, 2015; Babatolu and Akinnubi, 2016; Lasco et al., 2016). Studies also indicate that smallholder farmers are aware of climate changes and variability taking place in their localities are very resourceful in terms of response to the same, and act based on locally-developed (indigenous) knowledge and practices, which is diverse and site-specific (Corner, 2012; Tafali et al., 2017). Scientists agree that the role of smallholder farmers' knowledge in dealing with climate change adaptation cannot be over-emphasized and link it to the policy-making process (Newsham et al., 2011). In some cases the smallholder farmers' knowledge of climate change is purely based on indigenous knowledge, such as observation of birds' behaviour and flowering patterns of particular trees that dictate and predict droughts (Mashizha, 2019). In other instances, the smallholder farmers would acquire knowledge of climate change and its effects from climate change experts through extension and other farmer advisory services (The Commonwealth Education Hub, 2015). Smallholder dairy farmers' knowledge of climate change and its effects may also be related to their highest level of formal education (Odhiambo, 2014).

This study made an effort to establish the climate change perceptions and level of knowledge of smallholder dairy farmers, considering the influence of the same on the dairy industry. The specific study objectives were:

(1) To establish the perceived changes in climate over a 30-year period,
(2) To establish the effects of the climate changes on smallholder dairying in Southwestern Kenya,

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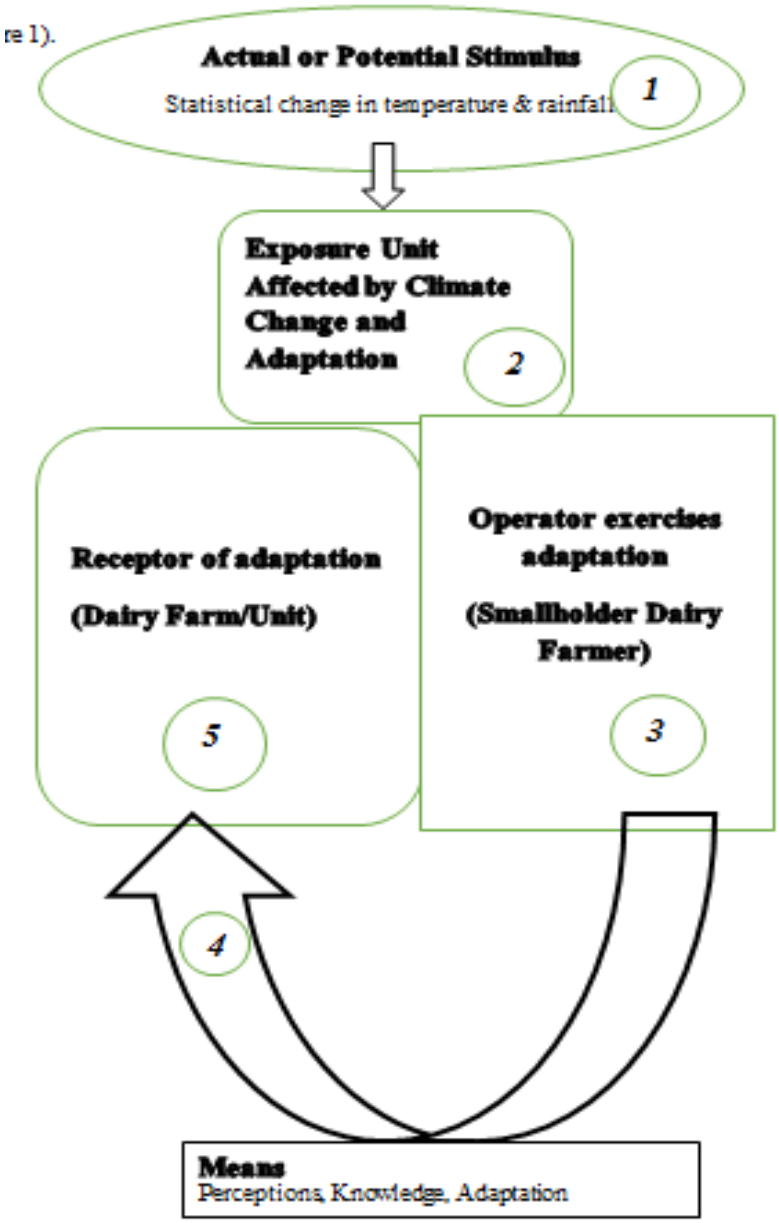

Figure 1. action theory of adaptation to climate change. 1, Changes in temperature and precipitation as recorded by meteorological station in the study area; 2, Household; 3, Smallholder dairy farmer; 4, Smallholder dairy farmer's perception and knowledge of climate change and climate change effects, and adaptation to climate change effects; 5, Smallholder dairy unit/farm.
Source: Adapted from Eisenack and Stecker (2010).

(3) To establish the relationship between the perceptions of smallholder dairy farmers to climate changes and their adaptive strategies to climate change effects,
(4) To establish the level of climate change knowledge of smallholder dairy farmers of Southwestern Kenya,
(5) To establish the relationship, if any, of this knowledge and their adaptive strategies to climate change effects.

Theoretical framework

The theoretical framework for this study was based on the Action Theory of Adaptation to Climate Change advanced by Eisenack and Stecker (2010) and on Adaptation Theory (Ziberman et al., 2012). The Action Theory of Adaptation to Climate Change advanced by

Eisenack and Stecker (2010) frames adaption as an individual or collective action, and build on established analyses of social action. The basic components of this theory are (collective) actors, means and ends of adaptation; where ends may be targeted at socio-economic or bio-physical units that are exposed to climate change, but also at the receptors (Figure 1).

This study endeavoured to appreciate the climatic changes taking place in the study area, with respect to temperature and precipitation (Ojango et al., 2017); with a view to assessing whether the smallholder dairy farmers (KAAA, 2016 perceive that the changes have actually taken place (Matekere, 2022), have an effect on the performance of the dairy farm (Huho et al., 2012) and the household (Otieno et al, 2021), and are making efforts to adapt to the effects to improve and sustain dairy productivity (Matekere, 2022). The study also endeavoured to establish the level of knowledge (Matekere, 2022). that the smallholder dairy farmers (KAAA, 2016) have of climate changes and their effects on dairying within the study site, and how this knowledge enables them to adapt to the changes for improved productivity and sustainability of dairy production in the farms (Huho et al., 2012).

Secondly, the study was hinged on Adaptation Theory (Ziberman et al., 2012), which emphasizes that, being responses to non-continuous changes, climate change adaptation involves understanding of discrete choices. To be considered successful, therefore, an adaptation must reduce the risk associated with climate change, or vulnerability to climate change impacts, to a pre-determined level, without compromising economic, social, and environmental sustainability. Considering adaptation at the micro (that is, farm or household) level, therefore, smallholder dairy farmers will require to make a selection among discrete strategies, which this study sought to investigate. By this theory, and borrowing from (Rogers, 2003), five distinct stages of adaptation are recognized, just as with adoption (Rogers, 2003). The first is awareness (that is realization that global warming and greenhouse gas [GHG] emission occur and linking the two), interest (that is, the realization that climate change may be harmful and should be addressed), evaluation (that is, the climate policy debate conducted at multiple levels), trial (that is, experimentation with various initiatives), and finally adoption (that is, new institutions, adoption of sustainable climate-smart livestock rearing practices).

In this study, therefore, efforts were made to establish the perceptions of smallholder dairy farmers regarding climatic changes (with respect to temperatures and precipitation) taking place in the study area; their perceived effect of the changes on smallholder dairying; and how they are adapting to the same. Efforts were also made to appreciate the knowledge smallholder dairy farmers have of climate change and climate change effects; and the relationships between smallholder dairy farmers' perceptions of climate changes and knowledge, and their adaptation strategies.

MATERIALS AND METHODS

Study site

The study was conducted in Migori County in Southwestern Kenya. Migori County is situated between latitude 1° 24' South and 1° 40'South and Longitude 34° East and 34° 50'East. The County borders Homa Bay County to the North, Kisii and Narok counties to the East, and the Republic of Tanzania to the South. It also borders Lake Victoria to the West and covers an area of 2,613.5 km^2 including approximately 478 km^2 of water surface (GoK, 2019a). The county comprises eight (8) sub-counties, namely: Rongo, Awendo, Uriri, Suna East, Suna West, Nyatike, Kuria West, and Kuria East. Four sub-counties namely Rongo, Awendo, Uriri, and Kuria West were selected for the study because they present a fairly homogenous climate, which also make them the dairy belt of the county (Figure 2). Within the four sub-counties, the study was confined to agro ecological zone LM_2, except in Rongo, where it was undertaken in UM_2 (GoK, 2019b).

Migori County has an inland equatorial climate modified by the effects of altitude, relief and Lake Victoria. Rainfall is generally continuous with little distinction between first and second rains. Annual rainfall averages between 700 and 1,800 mm. The first peak season comes over the months of March to May, and is reminiscent of the long rainy season; while the second peak season that is reminiscent of the short rains comes over the period of September-November. The two peaks are separated by a three-month period each, of June-August and December-February (GoK, 2019b). Precipitation received over the short rainy seasons in Migori County is on the increase, sometimes even being more reliable, well distributed and higher in amounts and spread (spatial and temporal) compared to the long rainy seasons (UNDP, 2012). On average February is considered the driest month, while April is the wettest month. Temperatures show mean annual minimum of 24°C and maximum of 31°C, with a diurnal range of about 7°C, relatively high humidity ranging between 40 and 95% (depending on season) and a potential evaporation of 1800 to 2000 mm per year (GoK, 2019b).

The county is predominantly into sugarcane production. However, in the four study sub-counties, smallholder dairy farming is rapidly gaining prominence. Land holding among the smallholder dairy farmers in the study site is 3 acres on average, with the farmers practicing mixed crop and dairy farming. A mix of stall-feeding (mainly at night and during milking) and tethering of the dairy herd to graze within the homesteads, or in paddocks is common; with crop residues being used to substitute commercial feeds. Characteristically, the smallholder dairy farmers of the study area keep cross-bred cattle, and depend largely on fodder from own farm, while a few lease land for fodder or buy fodder from neighbours (GoK, 2018). Most of the smallholders depend on water from the rivers, such as Kuja, Migori, Riana, Ongoche, and Sare (GoK, 2018). While some have sunk own shallow wells for watering the dairy cattle and for domestic use, others supplement with rain water harvesting (mainly in the form of roof catchment).

Study population and sampling

Records from Migori County Livestock Production Office indicated that the number of smallholder dairy farmers in the four sub-

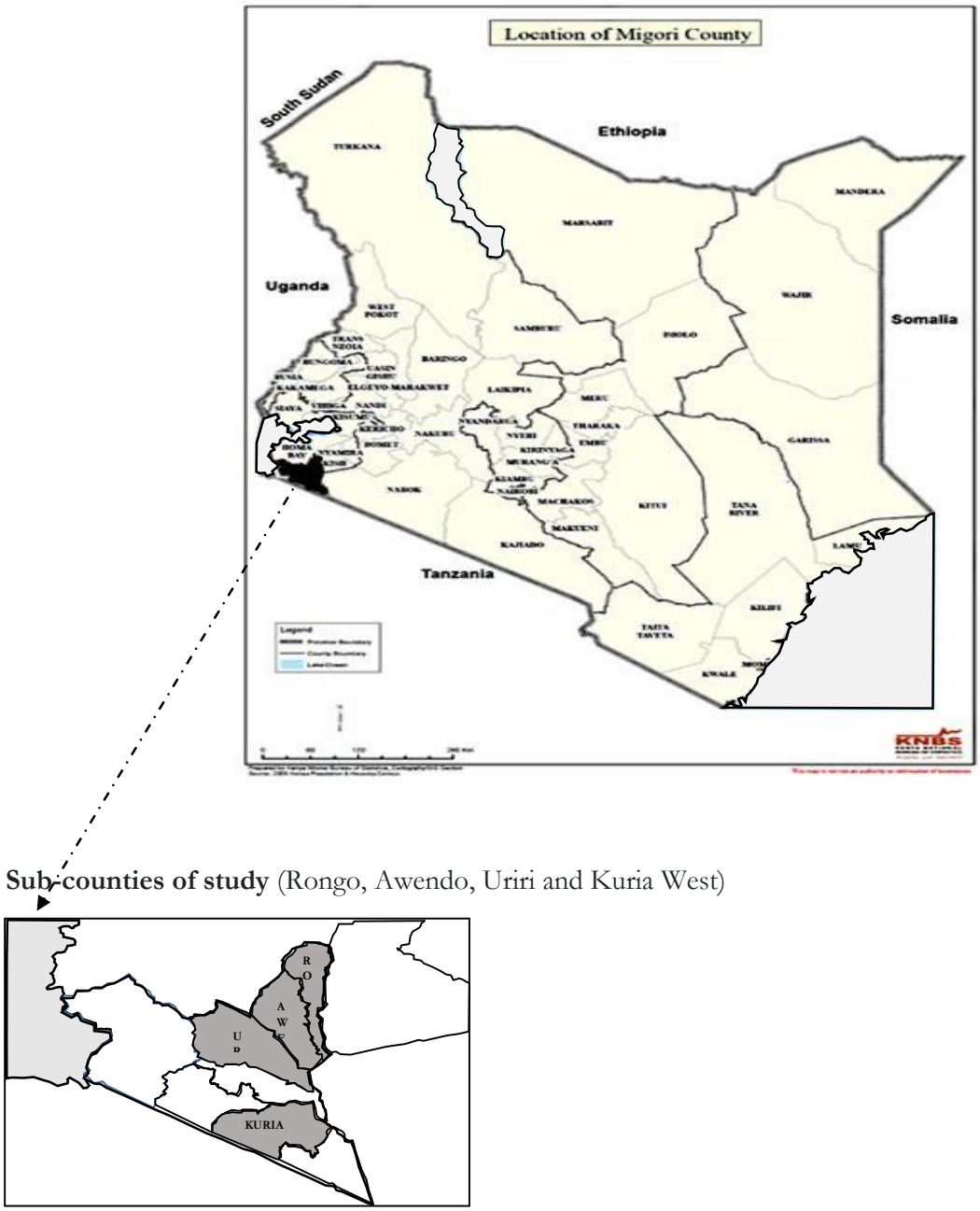

Figure 2. Map of the study area.

counties was 2,528 (GoK, 2013; Bosire et al., 2019). Yamane's Formula (Taro, 1967) for small populations less than 10,000 was used to determine the sample size as follows:

$$n = \frac{N}{1+N\,(e)^2} \quad (1)$$

where n = the desired sample size (for target populations less than 10,000); N =the population size; e = the level of precision or statistical significance set.

Therefore, given population of 2,528 smallholder dairy farmers in the selected agro-ecological zones (UM_2 and LM_2) of study within Migori County, for measurement at $p<0.05$, the desired sample size was:

$$n = \frac{2{,}528}{1+2{,}528\ (0.05)^2} = 345.355\ (\approx 345 \text{ smallholder dairy farmers}).$$

The study was conducted among 367 smallholder dairy farmer households proportionately distributed among the four sub-counties shown in Table 1.

Table 1. Sample size for the study.

Sub-county	Number of Smallholder Dairy Farmers	Desired sample Size	Actual sample size
Rongo	1,480	222	232
Awendo	88	13	13
Uriri	510	77	77
Kuria West	450	68	45
Total	2,528	380	367

Multi-stage sampling was used to obtain the sample. First, a visit was made to the sub-county livestock offices, from which a listing of all smallholder dairy farmers in each of the wards was obtained. Then, proportions of farmers in each of the wards were determined based on the populations listed. The same were used to distribute the desired sample size of 380 (adding 10% to 345 to take care of non-respondents) within the each of the wards.

Within each ward, the number of villages where smallholder dairying was being practiced was determined and proportionate sampling was again used to assign the number of farmers per village. Within each village, simple random sampling was used to pick households for inclusion into the study. On the other hand, for qualitative study, participants were identified and picked by purposive sampling, based on their role and level of involvement in smallholder dairying and meteorology.

On the other hand, for qualitative study, participants were identified and picked by purposive sampling, based on their level of involvement with smallholder dairying.

Data collection

Secondary data was obtained by review of reports and documents and from literature obtained from the internet, government offices and research stations (KALRO and Meteorological Department) using a data checklist. The data collected included the number of dairy cattle and smallholder dairy farmers in the four sub-counties of study, their socio-demographic profiles as well as temperature and precipitation data over a 30-year period.

A structured household survey questionnaire was used to obtain primary data from heads of smallholder dairy households with at least 10 years' experience in dairying. The questionnaire solicited responses on 19 perception and 15 knowledge measures and relating the same to respondents' adaptation to climate change effects. The knowledge tool had earlier on been standardized after administration to 3 select lead farmers who had been in smallholder dairying for over 15 years, a livestock extension expert who heads the Agriculture Sector Development Support Programme (ASDSP) in Migori County, and a Climate Change Expert leading livestock research at the Kenya Agriculture and Livestock Research Organization (KALRO)-Kisii for their knowledge on climate changes and their effects on smallholder dairying in the study area. Using the standardized tool, study respondents who scored above 50% had above-average level of climate change knowledge, while those with knowledge scores below 50% were taken to be below average level of climate change knowledge. In addition, qualitative data gathered by key informant interviews and focus group discussions was collected from heads of sections and departments in government agricultural research stations, departments, farms, farmer groups, and a Dairy Farmers' Cooperative Society in Ringo Sub-county. Non-participant observation, farm visits and transect walks were used to collect additional information for the study. An observation guide was prepared and used to facilitate the recording of information. The information was collected using a camera, recorder, and by note-taking.

Data analysis

For perceptions, quantitative data was analysed using percentages, with Binary logistic regression analysis being used to show which perception indicators greatly influenced adaptive strategies employed by smallholder farmers to adapt to climate change in Migori County. Data analysis considered each of the 19 perception indicators to climate changes taking place in the study site. A dichotomous Leikert Scale denoting a positive or negative deviation from the norm in the perception measure was used to rate the smallholder dairy farmers' perceptions of the climate changes in Migori County. The data set was then analysed using Binary Logistic Regression method to find out if this had any relationship with their adaptive strategies to climate change effects. In this regard, the 19 perception measures were analysed against each of the eight adoption measures singly and then jointly; with findings being presented at $p<0.05$.

The general regression equation in this case models the log odds of a binary outcome, y (adaptive strategy) as a function of predictor x (smallholder farmers' perceptions of climate changes) and is given as:

$$ln = \left[\frac{p}{1-p}\right] = \beta 0 + \beta 1x1 + \beta 2x2 + \cdots + \beta 19x19 \quad (2)$$

where p = proportion (probability) of y=1 and x1-x19 = the predictor perception indicators of climate changes in the study area, β0=The *log* odds of a smallholder dairy farmer being perceived to be an adopter of adaptive strategies to climate change effects (when xi =0) and β1-19= The *log* odds of a smallholder dairy farmer being perceived to be an adopter of adaptive strategies to climate change effects (when xi =1-19).

On the other hand, qualitative data relating to respondents' perception to climate changes that have taken place in the study site, their effects on smallholder dairying and smallholder dairy farmers' adaptive strategies to the effects, was first transcribed from the voice recordings into word. It was then analysed using the *Framework Approach,* both by case and theme.

For knowledge measurements, the overall score by each of the study respondents on the 15 knowledge indicators was obtained and the overall score for the sample calculated. The results were presented in terms of percentages to indicate the level of knowledge of the study respondents on matters climate change. To show relationships between the level of knowledge and the study respondents' adaptive strategies to climate change, Binary logistic regression analysis was again used. In this regard, each of the 15

questions on knowledge formed a knowledge measure. Using Binary Logistic Regression method, individual and joint relationships between these knowledge measures and the smallholder dairy farmers' adaptive strategies to climate change effects (Odhiambo et al., 2019) were determined. Multiple responses regarding each of the 8 measures of climate change adaptation were accepted. Results were then presented at $p<0.05$.

The general regression equation in this case models the log odds of a binary outcome, y (adaptive strategy) as a function of predictor x (smallholder farmers' perceptions of climate changes) and is given as:

$$ln = \left[\frac{p}{1-p}\right] = \beta 0 + \beta 1x1 + \beta 2x2 + \cdots + \beta 15x15 \quad (3)$$

where p = proportion (probability) of y=1, and x1-x15 = the predictor indicators of respondents' climate change knowledge, β0=The *log* odds of a smallholder dairy farmer being perceived to be an adopter of adaptive strategies to climate change effects (when xi =0) and β1-15= The *log* odds of a smallholder dairy farmer being perceived to be an adopter of adaptive strategies to climate change effects (when xi =1-15).

RESULTS AND DISCUSSION

Smallholder dairy farmers' perceptions of climate changes in Southwestern Kenya

Odhiambo et al., 2019 established that comparing the 1960s and 197's, the study respondents were of the perception that both day and night temperatures used to be colder than today. As from late 1970s and early 1980's, there has been a remarkable increase in day and night temperatures; with remarkable increases being recorded since the year 2000. Total amount of rainfall has shown a slight increase, comparing the 1960s and 2017 with notable distortions being observed with respect to rainfall patterns (seasonality, distribution, onset, duration, and frequency).

Tables 2 presents a summary of the perceptions as recorded from focus group discussants. The Table indicates that generally both day and night temperatures have risen, while rainfall seasons have become less predictable with distribution being very poor.

Table 3 presents a summary of the perceptions of climate changes in the study area as recorded from key informants over the periods 1960-2000 and 2001-2017. The Table shows that generally there has tended to be an increase in both day and night temperatures. As for rainfall, while the amounts have increased, rainfall has tended to be less reliable, with no clear seasonality. Intensity of rainfall has somehow increased, while distribution got worse. These findings were further corroborated by quantitative data from Meteorological Department (Figures 3 and 4).

From the study findings, the respondents were of the perception that there has been marked climatic changes in the study area since the year 2000, resulting in increases in temperature and total amount of rainfall, but whose distribution, intensity and reliability became very unpredictable. Whereas climatic change may have contributed to this, changes in farming patterns played a critical role. Available data indicate that both day and night temperatures in Migori have increased by about 0.3°C between 1982 and 2015; while mean annual rainfall amounts increased by about 195 mm between 1980 and 2013 (Awange et al., 2013). Interview with Migori County Director for Meteorological Services confirmed that temperatures have been steadily increasing with time, with global increase of 0.3°C being registered. These findings are consistent with climate change models for Lake Victoria Region of East Africa that predict increased temperatures due to climate change (Awange et al., 2013; Shah, 2015).

Study findings from focus group discussants that increase in temperature have largely contributed to changes in rainfall patterns; hence, climate change could be explained by the fact that the main driver of seasons is solar energy. Therefore, with climate change there is differential heating of the water bodies and the earth surface. Through water bodies we get water vapour, hence there is a relationship between temperature and climate change (Serdeczny et al., 2017).

Study findings regarding changes in rainfall amounts, seasonality, distribution and reliability are consistent with findings by Osman-Elasha (2009) and Serdeczny et al. (2017) whose predictions tend to paint a picture of higher rainfall amounts over eastern Africa as climate continues to change. The findings, however, differ from those by FAO (2011) in Lesotho, however.

Effects of climate changes on smallholder dairying in Southwestern Kenya

What is emerging in Migori County, as in Southwestern part of Kenya is coping with increased amounts of precipitation and higher temperature; with the amount of rainfall received over the short rainy seasons sometimes being even more reliable and well distributed (spatial and temporal) compared to the long rainy seasons (UNDP, 2012). These findings are consistent with those of Shah (2015) and Tripathi and Mishra (2017). These changes could also lead to disappearance of some crop and livestock species; hence, reduced forage amounts and variability for livestock. Besides, there is a likelihood of emergence of new strains of crop and livestock diseases and pests that may be difficult to manage (ICARDA/CCAFS, 2012). This would ultimately lead to reduced returns on investment from smallholder dairying (Hassan and Nhemachena, 2008). There would also be the challenge of getting the right cultivars and livestock breeds that would adapt to that kind of climate and remain in production under such harsh conditions (WWF, 2023). The findings, however, differ from those of

Table 2. Summary of perceptions of climate changes by focus group discussants.

Climatic parameter	Climate period 1 (1960-2000)	Climate period 2 (2001-2017)	Category of discussant
	Key statement	**Key statement**	
Day temp.	"In the '60s and up to around the year 2000, day temperatures were lower than what it is in 2017".	Since 2001, day has increasingly become warmer than before, to the extent that one would think the sun has somehow come slightly down and closer to the Earth".	Elders
Night temp.	"Nights used to be very cold in the '60s up to around the year 2000".	"In 2017 and since 2001, nights have tended to be very hot. As a result, people no longer use such heavy blankets as **Raymond's ®.**	Rongo Dairy Farmers' Cooperative Society
Rainfall seasons	"In the '60s and up to around the year 2000, seasons were very predictable. The long rains would come between March and May, while the short rains would come between August and October".	"The seasons have somehow become unpredictable since 2001, and are increasingly becoming so".	Elders
Rainfall reliability	"Long rains could easily be predicted, even from the direction of the winds and the clouds".	"As from the year 2001, and increasingly so over-time; rainfall is erratic and unpredictable".	Cham Gi Wadu Dairy and Multipurpose Group
Rainfall intensity	"Up to around the year 2000, rains would come in showers, but for a long time (called **kodh nyauru**)".	"In 2017 and since 2001, rains come for a short time, but of high intensity, violent and with thunder and lightning; and often very destructive winds".	Rongo Dairy Farmers' Cooperative Society
Rainfall distribution	"Rainfall used to be well distributed, both during the long and short rainy seasons".	"Rainfall has become erratic, and with an uneven temporal and spatial distribution".	Rongo Dairy Farmers' Cooperative Society

Ogalleh et al. (2012) and Wamugi (2016) that observed that rainfall amounts were generally decreasing, hence, making farmers to respond by diversifying enterprises, selling livestock and migrating to other parts of Kenya (Ogalleh et al., 2012)

Odhiambo et al. (2019) further established that the respondents opinioned that the changes in temperature and precipitation observed in Southwestern Kenya have had moderate to high impact on the smallholder dairy industry in the study area. Thus, respondents indicated that climate changes have led to increase in labour demand (42.2%; n=367); decrease in milk quality (41.1%; n=367); decline in milk production (38.7%; n=367); drying of nearest water sources (37.1%; n=367); scarcity of water (36.8%; n=367); and loss of livestock (35.1%; n=367). These have all had a moderate effect on smallholder dairy industry in the study area. On the other hand, increase in diseases and pests (61.0%; n=367), loss of pasture (42.2%; n=367), over grazing of land (41.1%; n=367), and under feeding of livestock (39.5%; n=367), all have had high impacts on the smallholder dairy industry in the study area.

Smallholder dairy farmers in the study area have in response to the climatic changes taking place adapted mainly by practicing mixed farming as seen in Figure 5 (96.5%; n=367), non-intensive dairying (95.1%; n=367), establishing own fodder (92.4%; n=367), rearing crossbred cattle (87.7%; n=367), keeping non-Friesian breeds and their crosses (87.5%; n=367), reducing dairy herd size to 2 (92.9%; n=367), relying mainly on household labour (94.6%; n=367), and maintaining a 10-year increasing trend in milk-income (68.4%; n=367) (Odhiambo et al., 2019). Generally, the smallholder dairy farmers would respond to the climatic changes in a manner that would both reduce their exposure to weather risks (Kasulo et al., 2012; Akhter and Olaf, 2016; Matunga et al., 2017) and ensure their sustainability in the dairy industry (Shah, 2015). This would assure the county of food and nutrition security and diversity, and reducing poverty (Akhter and Olaf, 2016). Findings by

Table 3. Summary of perceptions of climate changes by key informants.

Climatic parameter	Climate period 1 (1960-2000)	Climate period 2 (2001-2017)	Category of discussant
	Key statement	Key statement	
Day temp.	"Generally, day temperatures were lower compared to the period after 2001".	"Day temperatures have been hotter generally since 2001, but particularly much higher during the dry seasons".	Deputy Director-Livestock, Migori County
Night temp.	"Nights used to be very cold in the early days of 1960s and up to the year 2000".	"Night temperatures have generally become hotter since 2001; particularly during the dry seasons…"	
Rainfall amounts	"Other than such times as the heavy rainfall received all over Kenya around 1963 towards independence, Migori never used to receive much rainfall".	"Rainfall amounts have also increased since 2001".	Migori County Director for Environment
Rainfall seasons	"Farmers used to know of two rainy seasons-the long rains and short rains, and would plant appropriate crops for each season".	"Since 2001, seasonality of the rainfall is not so clearly demarcated"	
Rainfall reliability	"in the '60s and up to around 2000, rainfall used to be very predictable, making farmers realize good harvests".	"Since 2001, rainfall has become very unpredictable, with delays in the onset".	Migori County Director for Meteorology
Rainfall intensity	"In the '60s and up to around 2000, rainfall would come for a long time, but the intensity would be low compared to today".	"Since the year 2001, rainfall intensity has increased, with increased frequencies of hailstones".	
Rainfall distribution	"Generally, in the '60s and up to 2000, rainfall was well distributed".	"Rainfall distribution tends to have reduced and become poor over time, since 2001".	Migori County Commissioner for Cooperatives

Gbetibouo (2009), however, contradict these findings, since in South Africa, even though the farmers perceived climate was changing, two thirds did not make any efforts to adapt to the effects.

Relating smallholder dairy farmers' perception of climate changes in the study area with their adaptive strategies

Table 4 presents a summary of the relationships between perception indicators for temperature and precipitation and farming type, own fodder, breed type, and breeds kept adaptive strategies among the study respondents. Table 4 indicates that the perception that the study area had experienced a decrease in night temperature had a positive and statistically significant influence on the adoption of mixed farming method (Adjusted Odds=0.13; p=0.04). Similarly, the perception that the distribution of the short rains in the study area got worse positively and statistically significantly influenced farmers to establish their own fodder (Adjusted Odds=0.02; p=0.01). The perception that the study area had experienced no change in night temperatures had a slight positive, but statistically significant influence on farmers, making them rear non-Friesian breeds and their crosses that are better adapted to the local conditions (Adjusted Odds=0.08; p=0.02). Similarly, the perception that night temperatures in the study area had decreased had a more positive and statistically significant influence on farmers' adoption of better adapted breeds (Odds=0.19; p=0.01).

Table 5 presents a summary of the relationships between respondents' perceptions on changes in temperature and precipitation and number of dairy cattle kept, main source of farm labour, and dairy income trend adaptive strategies. Table 5 indicates that farmers' decision to reduce dairy herd size to 2 was significantly influenced by their perceptions that rainfall seasons have remained the same (Adjusted Odds=0.02; p=0.00); rainfall seasons have reduced (Adjusted Odds=0.10; p=0.03); rainfall duration in a single rainy episode during the long rains has not changed (Adjusted Odds=0.01; p=0.03); and that the intensity of the long rains has increased (Adjusted Odds=0.01; p=0.01). Farmers who

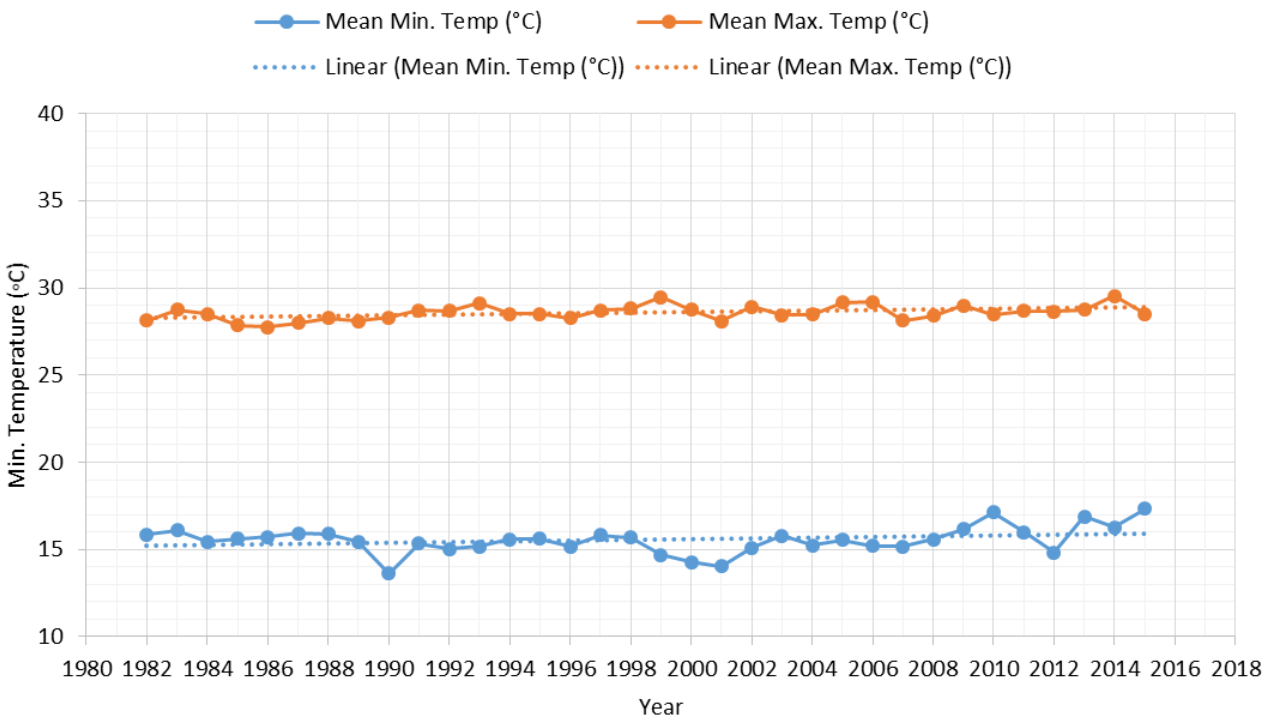

Figure 3. Mean minimum and maximum temperature trend for Migori (1982-2015)

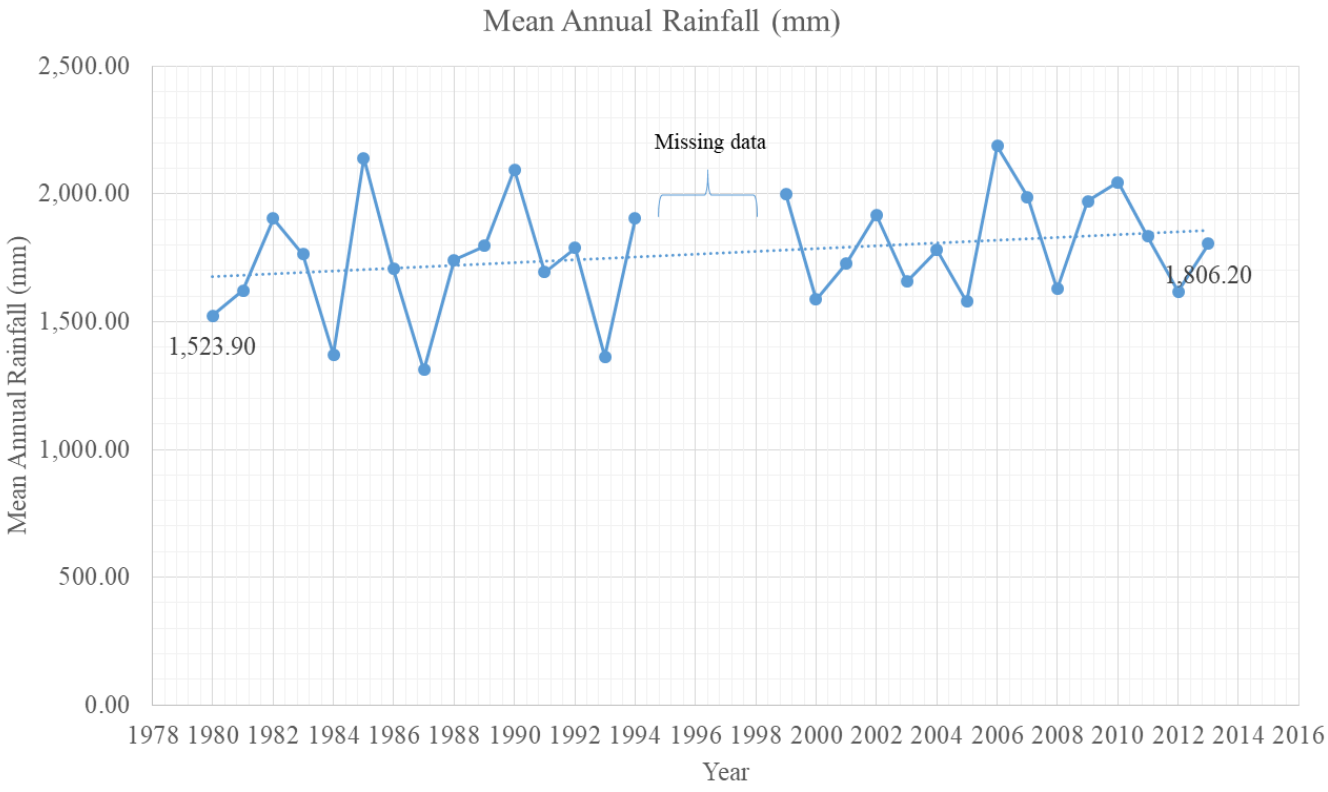

Figure 4. Mean annual rainfall trend for Migori (1980-2013).

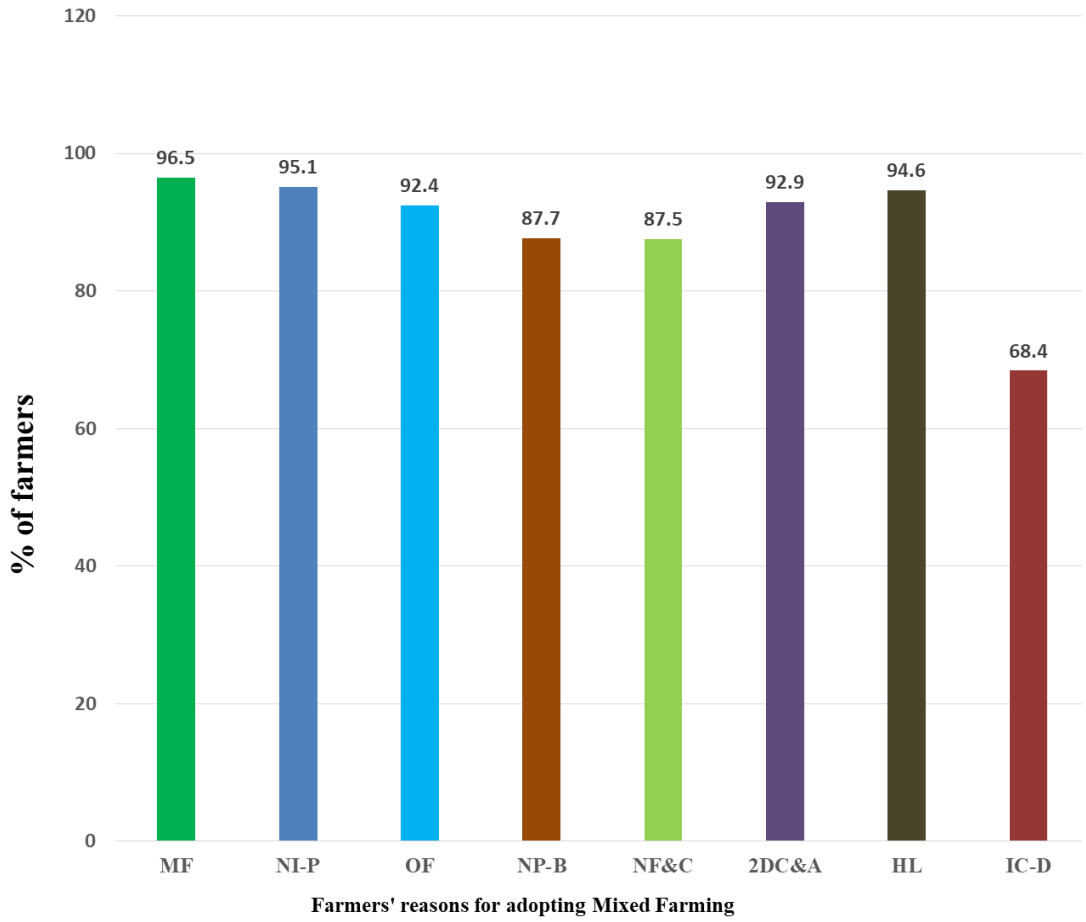

Figure 5. Distribution of respondents by climate change adaptive strategies* (n=367). *MF= Mixed Farming; NI-P= Non-Intensive Production; OF=Own Fodder; NP-B=Non Pure Breeds; NF&C=Non-Friesians and their crosses; 2DC&A=2 Dairy Cattle and Above; HL=Household Labour; and IC-D=Increasing trend in income from dairy.

experienced an increasing trend in income from milk sales were significantly influenced by their perceptions that the area had not experienced a change in day temperatures (Adjusted Odds=0.05; p=0.02); that the area had experienced a decrease in day temperature (Adjusted Odds=0.02; p=0.02); and that the onset of the short rains is very unpredictable (Adjusted Odds-0.37; p=0.04).

Available evidence point to the fact that climate change has taken place in Migori County, just as is the case in other parts of Southwestern Kenya, Kenya, sub Saharan Africa, and the world (Harvey et al., 2018; Marie et al., 2020; One Acre Fund, 2020). For smallholder dairy farmers of the study area, Kenya and the rest of the tropical world, what is critical is how the perceived changes affect the dairy industry, and in-turn, their livelihoods (One Acre Fund, 2020). How the changes affect their livelihoods would be seen on how they adapt to the climate change effects (Smit and Pilifosova, 2018). Tables 4 and 5 summarize the influence of the respondents' perceptions of climate changes on adaptation. As shown in Table 4, the study respondents' perception that there was no change in night temperature had a slight, but significant influence on their choice to rear adaptable non-Friesian breeds and their crosses (Adjusted Odds=0.08; p=0.02), while the perception that night temperatures had decreased had a s slight, but significant influence on their choice to practice mixed crop and dairy farming (Adjusted Odds=0.13; p=0.04). Regarding rainfall, the perception that the spatial and temporal distribution of the short rains got worse had a very slight, but significant influence on respondents' choice to establish own fodder (Adjusted Odds=0.02; p=0.01). From Table 5, the study the respondents' perception that there is no remarkable change in day temperatures (Adjusted Odds=0.05; p=0.02) and that day

Table 4. Relationships between climate change perceptions and Farming Type, Own Fodder, and Breed adaptability as Climate Change Adaptive strategies.

Perception indicator	Adjusted Odds values for perception indicators in relation to climate change adaptation								
	Perceptions & Farming Type			Perceptions & Own Fodder			Perceptions & adaptability of breeds kept		
	Odds	C.I	P-value	Odds	C.I	P-value	Odds	C.I	P-value
Experienced a decrease in night temperatures*	0.13	0.02-0.91	0.04	0.60	0.03-10.89	0.73	0.19	0.05-0.65	0.01
Experienced no change in night temperatures*	Ref.	n/a	1.00	n/a	n/a	1.00	0.08	0.01-0.64	0.02
Distribution of short rains is worse*	n/a	n/a	1.00	0.02	0.00-0.47	0.01	n/a	n/a	1.00

Table 5. Relationships between climate change perceptions and Dairy cattle kept, Main source of labour and Dairy income trend as Climate Change adaptive strategies.

Perception indicator	Adjusted Odds values for perception indicators in relation to climate change adaptation					
	Perceptions & No. of dairy cattle kept Adaptive Strategy			Perceptions & trend in dairy income Adaptive Strategy		
	Odds	C.I	P-value	Odds	C.I	P-value
No change in day temperatures experienced*	Ref.	n/a	1.00	0.05	0.00-0.60	0.02
A decrease in day temperatures experienced*	Ref.	n/a	1.00	0.02	0.00-0.62	0.02
Rainfall seasons have remained the same*	0.02	0.00-0.25	0.00	n/a	n/a	n/a
Rainfall seasons have reduced*	0.10	0.01-0.76	0.03	n/a	n/a	n/a
Onset of short rains is very unpredictable*	0.82	0.13-5.15	0.83	0.37	0.14-0.95	0.04
Duration in a single rainy episode (Long rains) has not changed*	0.01	0.00-0.64	0.03	n/a	n/a	n/a
Intensity of long rains has increased*	0.01	0.00-0.28	0.01	n/a	n/a	n/a

temperatures had somehow decreased (Adjusted Odds=0.02; p=0.02), both had a significant influence on realization of an increasing trend in income from milk sales. Moreover, Table 5 further indicates that the study respondents' perception that rainfall seasons have remained the same (Adjusted Odds=0.02; p=0.00), and that the length of the rainfall seasons have reduced (Adjusted Odds=0.10; p=0.03), both had a significant influence on the number of dairy cattle kept by the respondents. Regarding rainfall, Table 5 shows that respondents' perception that the onset of the short rains is very unpredictable (Adjusted Odds=0.37; p=0.04) significantly influenced the realization of an increasing trend in income from milk sales. Moreover, study respondents' perception that the rainfall duration in a single rainy episode (rainfall event) during the long rains has not changed (Adjusted Odds=0.01; p=0.03) and that the rainfall intensity during the long rainy season has increased (Adjusted Odds=0.01; p=0.01), both significantly influenced the number of dairy cattle kept by the study population.

The study findings indicate weak, but significant associations between the study respondents' perceptions on temperature and rainfall on climate change adaptation. The findings, which were also corroborated by Migori County Meteorological Officer, are consistent with those of other scholars (Tripathi and Mishra, 2017; Tadesse and Dereje, 2018). Nevertheless, the findings, differ with findings of several other studies (Ogalleh et al., 2012; Wamugi, 2016; Simotwo et al., 2018) that rainfall amounts were generally decreasing. The statistically significant relationships between the study respondents' perceptions of temperature and rainfall, in particular; differ with findings by Smit and Pilifosova (2018), who noted that respondents' perceptions had no statistically

significant relationship with climate change adaptation. Their argument was that all their study respondents were aware of climate variability, which was not the case for Migori.

Even though several modelling studies have predicated increasing extremities in weather patterns, such patterns as droughts and flood (Shah, 2015; Rojas-Downing et al., 2017; FAO, 2020), none of these were reported in the study area; except heavy erosion and strong wind storms that end up destroying crops and property. This is consistent with several findings (Kasulo et al., 2012; Ihemezie et al., 2018).

Generally, the smallholder dairy farmers would respond to the climatic changes in a manner that would both reduce their exposure to weather risks (Kasulo et al., 2012; Akhter and Olaf, 2016; Mutunga et al., 2017) and ensure their sustainability in the dairy industry (Shah, 2015; CGIAR, 2020). This would assure the county of food and nutrition security and diversity, and reducing poverty (Akhter and Olaf, 2016). The study respondents responded to the climate changes by adopting a number of soft, predictive and reactive adaptive measures, including adopting mixed crop and livestock farming, semi-intensive dairy production system, relying on household members for labour in the dairy enterprise, reducing dairy herd size to 2 cattle, establishing own fodder, rearing cross breed dairy cattle, keeping non Friesian breeds and their crosses that are more adaptable to local conditions, and ensuring an increasing trend in income from milk sales (Figure 10). Similar findings have been reported elsewhere, particularly for mixed farming, rearing of cross breed cattle, adaptable breeds, using household labour and establishing own fodder (Bagamba et al., 2012; Tadesse and Dereje, 2018; Marie et al., 2020). The study findings, however, differ with findings of other scholars (Gbetibouo, 2009), where, even though the farmers perceived climate was changing, two thirds did not make any efforts to adapt to the effects.

Hitayezu et al. (2017) posit that the likelihood of perceiving climate as changing is associated with both personal experience and analytical processing of climate information. Thus, Migori smallholder dairy farmers developed an effective impression on the changes in the climate of the area and the need to adapt, their educational level notwithstanding (Hitayezu et al., 2017). This could be associated with individual farmers' worldview, exposure to climate information from various sources, and support the farmers have received from different institutions to help them adapt (Fadina and Barjolle, 2018; CGIAR, 2020; GEF, 2020).

The study respondents being smallholder farmers are very vulnerable to climate change, since they are in the tropics, and with various socio-economic, demographic, and policy trends that limit their capacity to adapt to climate change (Ogalleh et al., 2012; Merton, 2017; Ihemezie et al., 2018).

Smallholder dairy farmers' level of knowledge on climate changes and climate change effects

Results indicated that the smallholder dairy farmers of Migori County have high knowledge of climate change and how it affects dairying; with 61% of the respondents scoring above average (n=367) as shown in Figure 6. Out of the 15 questions, the minimum score (n=367) was 4 (or 26%), while the maximum was 15 (or 100%), with a mean of 9.49 (or 63%) and a standard deviation of 2.96 (or 19.89%).

Farmers could acquire knowledge on climate change effects based on their educational background, exposure and experience in dairy farming. With knowledge comes exposure to new ideas, skills and information (Akhter and Olaf, 2016; Amuge and Osewe, 2017: Tegegne, 2017) that would enable the farmer to make rational decision to adopt climate change adaptation strategies (Odhiambo, 2014; Ochieng, 2015). Despite about 61% of the study respondents scoring above-average in terms of knowledge of climate change effects, some 31% (or 114) of the respondents scored 46% (that is, 7/15), which is below average shown in Table 6. This could be an indication that climate change is still an emerging challenge in the study area. Cumulatively, about 52% (or 192 of the respondents) scored 53% (or 8/15), which is considered average. Cumulatively, about 81% (or 297) of the respondents scored 80% (or 12/15) with about 12% (or 43) of the respondents scoring 100% (that is, 15/15).

The above-average level of knowledge of the study respondents on climate change and its influence on thesmallholder dairy industry is consistent with findings by Ogalleh et al. (2012) and Ochieng (2015) that farmers have an in-depth knowledge of climatic variability, enabling them to make rational decisions regarding coping and adaptive strategies.

In terms of performance per individual question, Table 7 shows that the question where majority (93.5%; n=367) of the study respondents scored right was the question regarding feed availability (question 1), while the question where majority of the study respondents (67%; n=367) scored wrong was the question on dairy cattle adaptationto local conditions (question 14).

Table 8 presents a summary of some indigenous knowledge of the study respondents, as captured during FGDs. From Table 8, it can be seen that the community has very rich indigenous technical knowledge (ITK) that the respondents are putting to use in climate change adaptation. This knowledge revolves around observing changes in wind directions and patterns, absence of some birds that used to herald beginning of rainy seasons, changes in types of sound produced by thunder, changes in water levels of water bodies, disappearance of certain forage types, and feelings of some people whose bodies would respond (by being painful all over) to herald the beginning of rainy seasons and vice versa; as

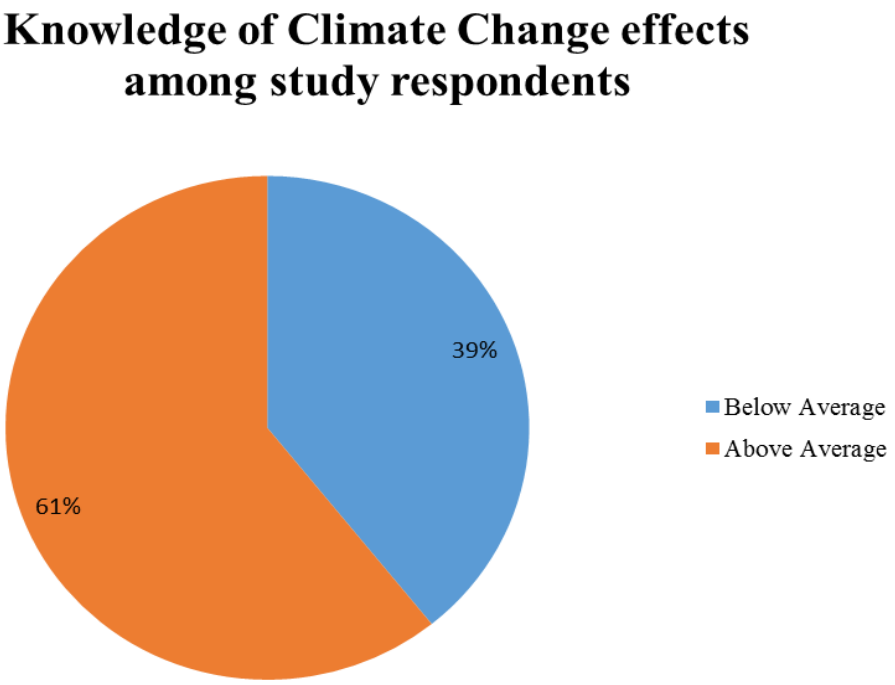

Figure 6. Distribution of study respondents by level of knowledge on climate change on smallholder dairying (n=367).

Table 6. Distribution of study respondents by score on knowledge.

Frequency of respondents	% of respondents	Total score (Out of 15)	Total score (%)	Cumulative frequency of respondents	Cumulative (%)
1	0.3	4	26	1	0.3
6	1.6	5	33	7	1.9
23	6.3	6	40	30	8.2
114	31.1	7	46	144	39.2
48	13.1	8	53	192	52.3
22	6.0	9	60	214	58.3
14	3.8	10	66	228	62.1
36	9.8	11	73	264	71.9
33	9.0	12	80	297	80.9
23	6.3	13	86	320	87.2
4	1.1	14	93	324	88.3
43	11.7	15	100	367	100.0
367	100.0	Total	100		

well as traditional rain-makers who would be consulted for divine interventions.

The rich indigenous knowledge existing within the community is very useful in complementing conventional knowledge on climate change and climate change adaptation, and could explain the high level of climate change adaption as noted by (Odhiambo et al., 2019).

Relationship between knowledge and climate change adaptation

A summary of knowledge measures with significant relationship with study respondents' climate change adaptations relating to farming type, production method, and establishment of own fodder is presented in Table 9

Table 7. Distribution of study respondents by knowledge by question (n=367).

Question No.	Question	Correct response (Yes/No)	Study respondents' responses					
			Yes		No		Correctly responding	
			Freq.	%	Freq.	%	Freq.	%
1	Disappearance of some forages (shrubs and herbs)	Yes	343	93.5	24	6.5	343	93.5
2	Emergence of some poisonous forages	Yes	323	88	44	12	323	88
3	Difficulties in controlling common dairy cattle parasites using conventional acaricides alone	Yes	316	86.1	51	13.9	316	86.1
4	Complications in dairy cattle disease management.	Yes	321	87.5	46	12.5	321	87.5
5	Drop in milk production from dairy cattle	Yes	286	77.9	81	22.1	286	77.9
6	Changes in available water and its quality for dairy cattle	Yes	285	77.7	82	22.3	285	77.7
7	Reduced adaptability of dairy cattle breeds to local conditions	Yes	246	67	121	33	246	67
8	No significant effect on the number and types of forages available for dairy cattle in this community	No	144	39.2	223	60.8	223	60.8
9	No significant effect on water availability for dairy cattle in this community	No	166	45.2	201	54.8	201	54.8
10	No significant effect on dairy cattle parasites	No	139	37.9	228	62.1	228	62.1
11	No significant effect on dairy cattle diseases	No	141	38.4	226	61.6	226	61.6
12	No significant effect on milk production from dairy cattle	No	163	44.4	204	55.6	204	55.6
13	No significant change in income earned from milk sales	Yes	205	55.9	162	44.9	205	55.9
14	Little effect on dairy cattle adaptability	No	246	67.0	121	33.0	121	33.0
15	Farmers unable to deal with climate change effects	No	160	43.6	207	56.4	207	56.4

Table 8. Summary of indigenous knowledge on climate change effects.

Knowledge area on climate change effect	Key statement	Category of discussant
Rainfall seasons	"In the '60's and up to around the year 2000, the Westerly wind indicated the onset of dry spells, and when the direction would change to Easterly, the indication would be the onset of rainy seasons. There were natural signs that the community would observe to predict the onset of the rains. Some black birds, for example, would be seen flying together; or water levels in wells could be observed to generally start rising up to herald the beginning of rainy seasons. Long rains would be heralded by the presence of such insects as butterflies and some birds, such as Magungu. As from 2001 onwards, seasons are not very easy to predict".	Elders
Dairy cattle feeds and feeding	**"**Chakre higa mar 2001, lum mar Obuya tinde onge, Lum mar Osinde be tinde olal, Sani lumbe machalo oto tinde onge".	
Water quantity and quality	"Since 2001, amounts of water available for cattle have decreased as much of the water drains to the Lake; pollution of the water bodies is also high, hence; the quality is also low, as a result of chemicals discharged from sugar factories".	

Table 8. Contd. Summary of indigenous knowledge on climate change effects.

Milk production	"In the '60s and up to around 2000, there was much milk, but less income. As from 2001, there has been less milk, but much more income because the price per litre of milk is much higher".	
Rainfall seasons	"In the '60s and up to around 2000 some villagers (especially the sick ones) would indicate by their feelings whether rains are about to fall or not. People would also observe certain physical features, such as natural vegetation-including such trees as Orembe, Bongu, Yago, Amboro, Maembe, and Ochuoga.	Cham Gi Wadu Dairy and Multipurpose Group, East Sakwa Farmers Development Group and Rongo Dairy Farmers' Cooperative Society
Adaptability of dairy breeds to local conditions	"In terms of adaptability; in the '60s and up to around the year 2000, Zebu cattle used to be well adapted and were fairly highly producing. In our community, since 2001 there has been an increase in zero-grazing and dairy cattle are highly producing, but not as much adaptable to the local climatic conditions. Moreover, farmers are tending to go for Ayrshire crosses, as Friesians have tended to be susceptible to tse-tse flies".	
Production system	"Most farmers have since the year 2001 tended to practice a mixture of zero-grazing and tethering. Free range is not practiced, as it exposes the cattle to ticks, hence; increasing chances of contracting tick-borne diseases".	
Dairy cattle feeds and feeding	"Some livestock feeds, such as olemo, oboro, modhno, oganga, osinde, pundo, bo dhok, etc. are no longer available, especially since the year 2001. Instead, we have new varieties of pastures, e.g. Boma Rhodes, Desmodium, etc. Nevertheless, the greatest challenge is that our farmers have tended to over-depend on Napier grass, and like feeding it green. Even when they incorporate Desmodium into livestock feeding, they also feed it green. The greens increase roughages and water content, thereby reducing milk production. Dry feeds on the other hand, help to increase milk production due to increased water intake (About 90% of milk being water)".	
Water quantity & quality	"Due to increases in population and increased land cultivation, especially after the year 2001; areas that used to provide water for livestock have been cultivated. This has affected the quantity and quality of water available for livestock. Most farmers have had to sink their own shallow wells. Poor farming methods have also led to this. People tend to cultivate the river rine areas".	
Diseases and parasites	"Since the year 2001, ticks and diseases have become so common compared to the '60s and the period before 2000. Many new diseases of livestock have come up, such as ECF, which is now more prominent and difficult to treat. Farmers have been advised to alternate the acaricides so as to break tick resistance. Most of the acaricides are no longer effective, as ticks have become resistant to them. Use of wrong method of application or using wrong appliances could also lead to manifestation of resistance."	
Milk production	"A lot of milk used to be available from local cattle in the 60's and 70's, but as of the period after 2001; despite us going for grade cattle, not much milk is being produced; even though production per cow has gone up".	

($p<0.05$). Table 9 indicates that adoption of mixed farming could potentially be influenced by knowledge that climate change affects forage availability (Crude Odds=0.12; p=0.04); has an effect on parasites (Crude Odds=0.13; p=0.05) and on diseases (Crude Odds=0.13; p=0.05) of dairy cattle; affects milk production (Crude Odds=0.10; p=0.03), and that dairy farmers are capable of dealing with climate change effects (Crude Odds=0.10; p=0.03). It could also potentially be influenced by the aggregate score of farmers' knowledge in climate change effects

(Crude Odds=0.18; p=0.01). These influences were, however, insignificant when all knowledge measures were jointly considered.

Similarly, the practice of non-intensive dairy production could potentially be influenced by knowledge of the fact that climate change affects available forage (Crude Odds=0.18; p=0.02), and that dairy farmers are capable of dealing with climate change effects (Crude Odds=0.24; p=0.03). This influence was, however, insignificant when all knowledge measures were jointly evaluated.

Regarding adoption of own fodder climate change adaptive strategy, Table 9 shows that the establishment of own fodder could potentially be influenced by knowledge of the fact that climate change has an effect on available forages (Crude Odds=0.33; p=0.01) and available water (Crude Odds=0.08; p=n/a). It could also potentially be influenced by knowledge of the fact that climate change affects parasites (Crude Odds=0.36; p=0.01) and diseases of dairy cattle (Crude Odds=0.44; p=0.04) and milk production (Crude Odds=0.35; p=0.01). Similarly, establishment of own fodder could potentially be influenced by knowledge of the fact that climate change affects earnings from dairy cattle (Crude Odds=0.19; p=n/a); adaptation of dairy cattle to local conditions (Crude Odds=0.14; p=0.01); and that farmers are capable of dealing with climate change effects (Crude Odds=0.34; p=0.01). These influences were, however, insignificant when all knowledge measures were jointly evaluated.

Table 10 presents a summary of the findings for relationships between farmers' climate change knowledge and the breeds of dairy cattle kept, number of dairy cattle kept, main source of labour, and dairy income trend as climate change adaptive strategies. Table 10 shows that adoption of crossbred cattle and use of family labour could all potentially be influenced by total score (Crude Odds=0.81; p=n/a) and percentage score (Crude Odds=0.97; p=n/a); and scores above average (Odds=0.08; p=0.01), respectively. These influences were, however, insignificant when all the knowledge measures were jointly considered. Farmers observing an increasing trend in income from milk sales could potentially be influenced by knowledge that climate change affects forage (Crude Odds=0.35; p=n/a) and water (Crude Odds=0.16; p=n/a) availability. It could also potentially be influenced by knowledge that climate change affects parasites (Crude Odds=0.18; p=n/a) and diseases (Crude Odds=0.24; p=n/a) of dairy cattle. In a like manner, the increasing trend in income from milk sales could potentially be influenced by knowledge that climate change affects milk production (Crude Odds=0.18; p=n/a); earnings from milk sales (Crude Odds=0.13; p=n/a); dairy cattle adaptability to local conditions (Crude Odds=0.07; p=n/a); and that farmers are capable of dealing with climate change effects (Crude Odds=0.32; p=n/a). These influences were, however, insignificant when all the knowledge measures were jointly examined. Thus, when jointly examined, only above average scores significantly influenced farmers to reduce herd sizes to 2 (Adjusted Odds=0.11; p=0.02).

Smallholder dairy farmers' knowledge on climate change effects could come from farmers' educational background, exposure to climate change information, interaction with other farmers through social networks and experience in dairy farming as noted by Jairo and Korir (2019). With knowledge comes exposure to new ideas, skills and information (Akhter and Olaf, 2016; Tripathi and Mishra, 2017; Tegegne, 2017) that would enable the farmer to make rational decision to adopt climate change adaptation technologies or strategies (Mashizha, 2019). In this study, although about 61% of the respondents scored above average on knowledge of climate change effects, giving the impression that the study respondents had high level of knowledge on climate change and its effects on smallholder dairying; as many as 31% of the respondents scored only 46%, which is below average. This could be an indication of the fact that through farmers' educational background, interaction with both formal and informal sources of climate change information, and own experience (Tripathi and Mishra, 2017; Jairo and Korir, 2019), study farmers had gained some critical level of knowledge on climate change and climate change effects on smallholder dairying in the study area. However, the fact that 31% of the respondents scored below average also indicates that climate change is still an emerging challenge in the study area (Mudombi-Rusinamhodzi et al., 2012; Kirui, 2014; Mashizha, 2019); for which smallholder dairy farmers need concerted support from all stakeholders as observed by (Newsham et al., 2011; Safdar et al., 2014; Steiner et al., 2020). The high (or above-average) level of knowledge of the study respondents on climate change and its influence on the smallholder dairy industry is consistent with findings by (Ogalleh et al., 2012; Ochieng, 2015; Babatolu and Akinnubi, 2016) that farmers have an in-depth knowledge of climatic variability, enabling them to make rational decisions regarding coping and adaptive strategies. It is worth noting that the rich indigenous knowledge existing within the community is also useful in complementing conventional knowledge on climate change and climate change adaptation, and could explain the high level of climate change adaption discussed in section 4.1. This is consistent with recommendations by Mashizha (2019) and Newsham et al. (2011) on the value of indigenous knowledge on climate change perceptions and adaptation, and the need to integrate this with conventional knowledge in recommending sustainable adaptation practices and formulating sound climate change adaptation policies and plans (Mashizha, 2019).

The high level of knowledge among Migori smallholder dairy farmers was also found to have a significant

Table 9. Relationships between Knowledge and Farming type, Production method and Own Fodder as Climate Change adaptive strategies.

Knowledge of climate change effect	Crude Odds (95% C.I.)			Adjusted Odds (95% C.I.)		
	Odds	C.I	P-value	Odds	C.I	P-value
Knowledge of climate change effect and Farming Type Adaptive Strategy						
No effect on available forages (Yes)						
No*	0.12	0.02-0.96	0.04	Ref.	Ref.	0.25
No effect on parasites of dairy cattle (Yes)						
No*	0.13	0.02-1.01	0.05	Ref.	Ref.	0.38
No effect on diseases of dairy cattle (Yes)						
No*	0.13	0.02-0.99	0.05	Ref.	Ref.	0.28
No effect on milk production (Yes)						
No*	0.10	0.01-0.77	0.03	Ref.	Ref.	0.34
Dairy farmers can't deal with climate change effects (Yes)						
No*	0.10	0.01-0.79	0.03	Ref.	Ref.	0.32
Total Score Category (Below Average)						
Above Average*	0.18	0.05-0.68	0.01	0.36	0.01-11.32	0.56
Knowledge of climate change effects and Production Method Adaptive Strategy						
No effect on available forages (Yes)						
No*	0.18	0.04-0.80	0.02	1.21	Ref.	0.98
Dairy farmers can't deal with climate change effects (Yes)						
No*	0.24	0.07-0.86	0.03	1.78	Ref.	0.94
Knowledge of climate change effects and Own Fodder Adaptive Strategy						
No effect on available forages (Yes)						
No*	0.33	0.15-0.73	0.01	14.93	Ref.	0.66
No effect on water available (Yes)						
No*	0.08	0.02-0.29	n/a	1.56	Ref.	0.94
No effect on parasites of dairy cattle (Yes)						
No*	0.36	0.16-0.80	0.01	39.18	Ref.	0.55
No effect on diseases of dairy cattle (Yes)						
No*	0.44	0.20-0.96	0.04	64.60	Ref.	0.50
No effect on milk production (Yes)						
No*	0.35	0.15-0.80	0.01	38.46	Ref.	0.55
No effect on earnings from dairy (Yes)						
No*	0.19	0.06-0.56	n/a	21.49	Ref.	0.62
Dairy cattle still well adapted (Yes)						
No*	0.14	0.03-0.61	0.01	9.57	Ref.	0.72
Dairy farmers can't deal with climate change effects (Yes)						
No*	0.34	0.15-0.77	0.01	42.26	Ref.	0.55

Table 10. Relationships between knowledge and dairy cattle types, number of dairy cattle kept, main source of farm labour, and trend in dairy income as climate change adaptive strategies.

Knowledge of climate change effect	Crude Odds (95% C.I.)			Adjusted Odds (95% C.I.)		
	Odds	C.I	P-value	Odds	C.I	P-value
Knowledge of climate change effects and Dairy Cattle Types Adaptive Strategy						
Total score*	0.81	0.73-0.90	n/a	n/a	n/a	n/a
% Score*	0.97	0.96-0.98	n/a	2.09	0.52-8.46	0.30
Knowledge of climate change effects and Number of Dairy Cattle kept Adaptive Strategy						
Total Score Category (Below Average)						
Above average*	1.15	0.51-2.57	0.74	0.11	0.02-0.72	0.02
Knowledge of climate change effects and Main source of farm labour Adaptive Strategy						
Total Score Category (Below Average)						
Above average*	0.08	0.01-0.57	0.01	n/a	n/a	1.00
Knowledge of climate change effects and trend in dairy income Adaptive Strategy						
No effect on available forages (Yes)						
No*	0.35	0.21-0.57	n/a	0.14	Ref.	0.64
No effect on water available (Yes)						
No*	0.16	0.10-0.28	n/a	0.59	Ref.	0.90
No effect on parasites of dairy cattle (Yes)						
No*	0.18	0.10-0.32	n/a	0.86	Ref.	0.97
No effect on diseases of dairy cattle (Yes)						
No*	0.24	0.14-0.41	n/a	0.30	Ref.	0.77
No effect on milk production (Yes)						
No*	0.18	0.11-0.31	n/a	0.45	Ref.	0.85
No effect on earnings from dairy (Yes)						
No*	0.13	0.08-0.22	n/a	0.68	Ref.	0.93
Dairy cattle still well adapted (Yes)						
No*	0.07	0.04-0.11	n/a	1.76	Ref.	0.89
Dairy farmers can't deal with climate change effects (Yes)						
No*	0.32	0.20-0.53	n/a	0.37	Ref.	0.82

relationship with climate change adaptation. Total score (above average) significantly influenced the number of dairy cattle kept (Adjusted Odds=0.11; p=0.02). This implies that the overall level of knowledge smallholder dairy farmers have of climate change and its effects on dairying is the most important determining factor regarding knowledge's influence on smallholder dairy farmers' climate change adaptation. This is consistent with findings by Ogalleh et al. (2012), yet strengthening the findings by Bagamba et al. (2012) that there is still a considerable knowledge gap on climate change impact, vulnerability, and adaptation to climate variability and change. Tripathi and Mishra (2017) took note of the fact that knowledge of climatic perceptions and adaptations are vital entry points for decision making, implying that based on their worldview (perceptions), experience and knowledge of climatic changes and their impact on smallholder dairying; Migori smallholder dairy farmers have managed to adapt fairly well to climate change effects. Generally, knowledge of climate change and its effects on smallholder dairying tended to have more influence on smallholder dairy farmers' choice of adaptive

strategies related to farming and production system, breed choice, and feeding strategy; and ended up enabling them to experience an increasing trend in income from sale of milk from the dairy cattle (Amuge and Osewe, 2017; Steiner et al., 2020).

These findings suggest that there is a direct and positive relationship between knowledge and climate change adaptation, unlike what Tripathi and Mishra (2017) established in India. The adaptive practices that are most directly and positively influenced by knowledge include: mixed crop and dairy farming, keeping of non-pure (that is, crosses) dairy cattle breeds, and adoption of the household as main source of farm labour. This further confirms the hypothesis that farmers' decision making is complex and is based not only on their perceptions, but also on their knowledge and experience regarding the aspect of farming (Rojas-Downing et al., 2017; Fadina and Barjolle, 2018; WWF, 2023).

Moreover, knowledge about what farmers could do to adapt to climate change effects, and the effect of climate change on adaptability of breeds to local conditions, available forage, water, parasites and diseases of dairy cattle; milk yields, and earning from dairy farm through milk sales; directly and positively influenced Migori smallholder farmers' adaptive practices to climate change effects. The study findings agree with those of Ogalleh et al. (2012), but contradict findings by Hitayezu et al. (2017).

Knowledge on climate change by the respondents could be a complex process that is influenced by farmers' age, educational level, experience in smallholder dairying, the strength of the farmers' social networks, and formal and informal access to climate change information as noted by Newsham et al. (2011); Mashizha (2019); Jairo and Korir (2019).

CONCLUSIONS AND RECOMMENDATIONS

From the findings, study farmers' decision to adopt climate change adaptation strategies was influenced both by their perceptions of changes in temperature and precipitation, and knowledge of climate change and climate change effects. Total score on knowledge measure had the highest influence on the study respondents' decision to adopt climate change adaptation practices relating to farming and production system, breed choice, and feeding strategy; and experiencing an increasing trend in milk income. Thus, knowledgeable farmers are better adapted to climate change effects. The study recommends that governments should invest more in infrastructure for accurate weather prediction and dissemination, and put in place policies and institutional frameworks to support local adaptation by smallholder farmers to climate change effects. Moreover, governments and stakeholders should incorporate farmers' indigenous knowledge in developing climate change adaptation plans, strategies and policies.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Appendices

Appendix I: QUESTIONNAIRE FOR SMALLHOLDER DAIRY FARMERS

DETERMINANTS OF ADAPTIVE STRATEGIES TO CLIMATE CHANGE OF SMALLHOLDER DAIRY FARMERS OF MIGORI COUNTY, KENYA

SURVEY QUESTIONNAIRE

AEZ:____Sub-County:_____Ward:_____Location:_____

Sub-location:_____Village:_____

HH No.:_____S/No.:_____Interviewer:_____

Interview Date:_____ Interview start:_____Interview end:_____

Informed Consent Page

Your household is among those randomly selected from this Village to participate in this study. We would like to find out some information about climate change and dairy farming that you undertake. The information will be useful in helping to improve smallholder dairy famers' level of understanding, preparedness and coping strategies to climate change effects so as to remain in production; make profits and make significant contributions to Kenya's economic growth and development.

Participation in this study is purely voluntary, and we can only promise that we shall share with you and others the study findings. If you agree, we will ask you some questions regarding the above-mentioned aspects. We will try our best to keep the information you give us very confidential. We will not tell anyone you took part in this study. Your name will not be written down. You don't have to answer any questions if you don't want to, and you are free to withdraw from the study at any time should you find that you are unable to continue. No one will be upset with you.

Do you agree to take part? ***(Please tick)*** □ Yes □ No

Note: Only proceed with the interview if the respondent consents

Name of Respondent:_____I.D. Number:_____

Telephone:_____Sign:_____Date:_____

SECTION A: SOCIO-DEMOGRAPHIC CHARACTERISTICS OF HOUSEHOLD

1. Sex of respondent***(Tick)***

1	**Male**		**2**	**Female**	

2. How old are you? _____***(Please indicate date of Birth)***

3. What is your marital status? ***(Tick)***

1	**Single**		**3**	**Divorced**	
2	**Married**		**4**	**Separated**	
5	**Widow**		**6**	**Widower**	
66	**Other (Specify)**				

4. What is your highest level of formal education? ***(Tick)***

0	**Never went to school**		**1**	**Completed Lower Primary Education (Class 1-3)**	
2	**Did not complete Upper Primary education**		**3**	**Completed Primary Education**	
4	**Did not complete Secondary education**		**5**	**Completed Secondary education**	
6	**Completed Polytechnic after Pri. Education**		**7**	**Completed Polytechnic after Sec. Education**	
8	**Completed Informal/Adult Education**		**9**	**Completed Certificate Level of education**	
10	**Completed Diploma Level of education**		**11**	**Completed First Degree**	
12	**Post-graduate Degree**		**99**	**Other (Specify)**	

5. How many people have been living in this house, cooking and eating together from the same pot over the past six months?_____***(please probe to establish the correct household size)***

6. What is your level of experience (in years) in dairy farming?_____***(Please indicate year when respondent begun practicing dairying to establish correct level of experience)***

7. What is your total area of land in acres?_____acres

8. How much is your household's total monthly income (from all sources) in Kshs.?_____

SECTION B: PERCEPTION OF CLIMATE CHANGES IN MIGORI COUNTY

Comparing the climate of this community now and the past fifteen years, what changes would you say have taken place regarding the following parameters of climate? **(Please probe to establish the correct position)**

9. What observable/noticeable changes in day temperatures would you say have taken place in your community comparing now and fifteen years ago?**(Please probe to tick correct response given)**

1. Experienced a rise [ ] 2. Experienced no change [ ]

2. Experienced a decrease [ ]

10. What observable/noticeable changes in night temperatures would you say have taken place in your community comparing now and fifteen years ago?**(Please probe to tick correct response given)**

1. Experienced a rise [ ] 2. Experienced no change [ ]

3. Experienced a decrease [ ]

11. What observable/noticeable changes in rainfall seasons would you say have taken place in your community comparing now and fifteen years ago?**(Please probe to tick correct response given)**

1. Seasons have increased [ ] 2. Seasons have remained the same [ ]
3. Seasons have reduced [ ] 4. We have rains throughout the year [ ]

12. What observable/noticeable changes in rainfall amounts for the short rainy season would you say have taken place in your community comparing now and fifteen years ago?**(Please probe to tick correct response given)**

1. Amounts have increased [ ] 2. Amounts have remained the same [ ]
3. Amounts have reduced [ ]

13. What observable/noticeable changes in rainfall amounts for the long rainy season would you say have taken place in your community comparing now and fifteen years ago?**(Please probe to tick correct response given)**

1. Amounts have increased [ ] 2. Amounts have remained the same [ ]
3. Amounts have reduced [ ]

14. What observable/noticeable changes in onset of rainfall for the short rainy season would you say have taken place in your community comparing now and fifteen years ago?**(Please probe to tick correct response given)**

1. Onset nowadays delays [ ] 2. Onset comes earlier than fifteen years ago [ ]
3. Onset is very unpredictable [ ]

15. What observable/noticeable changes in onset of rainfall for the long rainy season would you say have taken place in your community comparing now and fifteen years ago?**(Please probe to tick correct response given)**

1. Onset nowadays delays [ ] 2. Onset comes earlier than fifteen years ago [ ]
3. Onset is very unpredictable [ ]

16. What observable/noticeable changes in duration of rainfall (total length)for short rainy season would you say have taken place in your community comparing now and fifteen years ago?**(Please probe to tick correct response given)**

1. Duration has reduced [ ] 2. Duration has remained the same [ ]
3. Duration has increased [ ]

17. What observable/noticeable changes in duration of rainfall (total length) for long rainy season would you say have taken place in your community comparing now and fifteen years ago?**(Please probe to tick correct response given)**

1. Duration has reduced [ ] 2. Duration has remained the same [ ]
3. Duration has increased [ ]

18. What would you say of the period taken during a single raining episode during the short rainy season in your community comparing now and fifteen years ago?**(Please probe to tick correct response given)**

1. Is shorter [ ] 2. Has not changed [ ] 3. Is longer [ ]

19. What would you say of the period taken during a single raining episode during the long rainy season in your community comparing now and fifteen years ago?**(Please probe to tick correct response given)**

1. Is shorter [ ] 2. Has not changed [ ] 3. Is longer [ ]

20. What would you say of the distribution (spread/area covered by rainfall) during the short rainy season in your community comparing now and fifteen years ago?**(Please probe to tick correct response given)**

1. Is better [ ] 2. Has not changed [ ] 3. Is worse [ ]

21. What would you say of the distribution (spread/area covered by rainfall) during the long rainy season in your community comparing now and fifteen years ago?**(Please probe to tick correct response given)**

1. Is better [ ] 2. Has not changed [ ] 3. Is worse [ ]

22. What would you say of the distribution (spread/area covered by rainfall) during any single rainy episode during the short rainy season in your community comparing now and fifteen years ago?**(Please probe to tick correct response given)**

1. Is better [ ] 2. Has not changed [ ] 3. Is worse [ ]

23. What would you say of the distribution (spread/area covered by rainfall) during any single rainy episode during the long rainy season in your community comparing now and fifteen years ago?**(Please probe to tick correct response given)**

1. Is better [ ] 2. Has not changed [ ] 3. Is worse [ ]

24. What observable/noticeable changes in intensity of rainfall (strength) for the short rains would you say have taken place in your community comparing now and fifteen years ago?**(Please probe to tick correct response given)**

1. Intensity has reduced [ ] 2. Intensity has remained the same [ ]
3. Intensity has increased [ ]

25. What observable/noticeable changes in intensity of rainfall (strength) for the long rains would you say have taken place in your community comparing now and fifteen years ago?**(Please probe to tick correct response given)**

1. Intensity has reduced [ ] 2. Intensity has remained the same [ ]
3. Intensity has increased [ ]

26. What observable/noticeable changes in intensity of rainfall (strength) during any single rainy episode for the short rains would you say have taken place in your community comparing now and fifteen years ago?

1. Intensity has reduced [ ] 2. Intensity has remained the same [ ]
3. Intensity has increased [ ]

27. What observable/noticeable changes in intensity of rainfall (strength) during any single rainy episode for the long rains would you say have taken place in your community comparing now and fifteen years ago?

1. Intensity has reduced [ ] 2. Intensity has remained the same [ ]
3. Intensity has increased [ ]

SECTION C: KNOWLEDGE OF CLIMATE CHANGE EFFCETS ON SMALLHOLDER DAIRY INDUSTRY IN MIGORI COUNTY

For each of the following set of questions, kindly respond by stating **"Yes"** or **"No",** based on your understanding of the changes in climate that have taken place in this community over the past fifteen years, and your experience in dairy farming.***(Please use the score guide provided to award 1 for all correct responses given and 0 for all incorrect responses given):***

28. Because of changes in climate, some forages (shrubs and herbs) that dairy cattle used to take as feeds have disappeared from the community.

1	**Yes**	
2	**No**	

Score:___

29. Because of changes in climate, new types of forages (shrubs and herbs) have emerged, some of which are poisonous to dairy cattle in this community.

1	**Yes**	
2	**No**	

Score:___

30. Because of changes in climate, it is nowadays more difficult to control common pests/parasites like ticks affecting dairy cattle using the conventional chemicals (acaricides) alone.

1	**Yes**	
2	**No**	

Score:___

31. Because of changes in climate, diseases that used to be easy to manage are becoming very complicated, often leading to death of dairy cattle in this community.

1	**Yes**	
2	**No**	

Score:___

32. Because of changes in climate, milk produced by dairy cattle has somehow gone down in this community.

1	**Yes**	
2	**No**	

Score:___

33. Because of changes in climate, available water and its quality for dairy cattle in this community has changed.

1	**Yes**	
2	**No**	

Score:___

34. Because of changes in climate, the breeds of dairy cattle that used to live well and produce well (i.e. adaptable) to the environment in this community no longer live well and do well.

1	**Yes**	
2	**No**	

Score:___

35. Changes in climate have not had any significant effect on the number and types (variety) of forges (shrubs and herbs) available for dairy cattle in this community.

1	**Yes**	
2	**No**	

Score:___

36. Changes in climate have not had any significant effect on the water (amounts and quality) available for dairy cattle in this community.

1	**Yes**	
2	**No**	

Score:___

37. Changes in climate have not had any significant effect on the number and types of parasites affecting dairy cattle in this community.

1	**Yes**	
2	**No**	

Score:___

38. Changes in climate have not had any significant effect on the number and types of diseases affecting dairy cattle in thus community.

1	**Yes**	
2	**No**	

Score:___

39. Changes in climate have not had any significant effect on milk produced from dairy cattle in this community.

1	**Yes**	
2	**No**	

Score:___

40. Despite changes in climate, the income earned by dairy cattle farmers in this community from milk sales has not changed much.

1	**Yes**	
2	**No**	

Score:___

41. Despite changes in climate, dairy cattle have continued to be well adaptable to living in the environment in this community.

1	**Yes**	
2	**No**	

Score:___

42. Dairy cattle farmers of this community cannot deal with effects of changes in the climate that affects their dairy enterprise.

1	**Yes**	
2	**No**	

Score:___

Researcher's Section: Total Score_____/15=_____%

SECTION D: ADAPTIVE STRATEGIES TO EFFECTS OF CLIMATE CHANGE

43. What problems do you face as a smallholder dairy farmer in an effort to adapt to effects of climate changes that have occurred in your community?***(Tick all that are mentioned).***

Code	Climate Change Effect	Low effect (1)	Moderate effect (2)	High effect (3)
1	Pasture loss			
2	Drying of nearest water sources			
3	Loss of livestock			
4	Under feeding of livestock			
5	Increase in diseases and pests			
6	Selling of livestock at throw away prices			
7	Long walk in search of water and pasture			
8	Over grazing of land			
9	Poor market for the livestock products due to poor quality			
10	More human labour required			
11	Increase in livestock-human –wildlife conflicts			
12	Reduced milk production			
13	Water scarcity			

44. What type of farming do you practice in your smallholder dairy farm?***(Tick as appropriate)***

1	0
Mixed crop and dairy farming	***Pure dairy farming***

45. Considering the effects of climate change in your area, why do you prefer the type of farming you practice?***(Tick all that are mentioned)***.

Code	Reason for preferring production method	Yes (1)	No (2)
1	Helps to spread risk/reduces risk of total loss		
2	Allows for complementarity of enterprises (enterprises benefit from one another)		
3	Reduces overall cost of production		
4	Assures sustainability in business		
5	Increases household income		

6 Allows for gathering information about farming from several different sources

7 Easy to market produce

46. What production method do you employ in your dairy farm?

1	0
Non-intensive dairy farming*(includes all methods where zero grazing is integrated with tethering and/or free range)*	***Intensive dairy farming*** *(i.e. pure zero-grazing)*

47. Considering the effects of climate change in your area, why do you prefer the production method that you have adopted in your farm?***(Tick all that are mentioned)***.

Code	Reason for preferring production method	Yes (1)	No (2)
1	Reduces labour demand		
2	Gives flexibility to engage in other activities		
3	Allows for efficient utilization of scarce feed resources		
4	Reduces cost of parasite and disease control in the farm		
5	Reduces chances of theft of dairy cattle		
6	Reduces cost of watering the animals		
7	Allows for utilization of farm by-products		
8	Allows for close monitoring of all groups of dairy animals in farm		

48. Which is your main source of fodder for the dairy cattle that you keep?

1	0
Own farm *(includes both green and dry/preserved fodder obtained from farmer's own farm)*	***Not from own farm*** *(includes green and dry/preserved fodder from elsewhere, and includes concentrates from Agrovets)*

49. Considering the climate change effects in your area, are you satisfied with your current sources of feeds for your dairy cattle?

1. Satisfied [ ] 2. Not Satisfied [ ]

50. Which types of breeds of dairy cows do you keep in your farm? ***(Please observe and tick appropriately).***

1	0
Non Pure breed *(i.e. Cross breeds)*	***Pure breeds***

51. Considering the effects of climate change in your area, why do you prefer to keep the type of breeds you have in your farm? ***(Tick all that are mentioned)***.

Code	Reason for preferring production method	Yes (1)	No (2)
1	They are more adaptable to the local climate		
2	They are more parasite-and disease-tolerant		
3	They have a comparatively lower feed and water demand		
4	They are high yielding		
5	They mature fast and come into production early		
6	They have high twinning ability		
7	They have comparatively low labour demand		
8	Allows for close monitoring of all groups of dairy animals in farm		
9	They are more affordable		

52. Which breeds of dairy cattle do you keep in your farm?***(Please observe and tick appropriately).***

1	0
Ayrshires, Guernseys, Jerseys and/or their crosses	***Friesians and their crosses***

53. Considering the effects of climate change in your area, why do you prefer to keep these breeds of dairy cows in your farm?***(Tick all reasons given).***

Code	Reason for preference	Yes (1)	No (2)
1	High milk production		
2	High butterfat content		
3	Adaptability to local climatic conditions		
4	Adaptability to common diseases and parasites		
5	Low feed requirements		
6	Low water requirements		
7	Early maturing (Comes into calving early)		
8	High twinning ability		
9	Affordability of the animal		

54. How many dairy cows do you keep?***(List total number)***_____

1. Two and above [ ] 0. Less than two [ ]

55. Considering the effects of climate change in your area, why do you prefer to keep this number of dairy cows in your farm?***(Tick all reasons given).***

Code	Reason for preference	Yes (1)	No (2)
1	Easy to manage		
2	Gives high returns per unit area		
3	Have less labour requirement		
4	Commensurate to the feed resources available in my farm		

5	Commensurate with my animal health management level/kills
6	Commensurate with my animal housing management level/skills
7	Commensurate with my animal fertility management level/skills
8	Advised by extension agents to keep that number
9	Affordability of the animals
10	High returns when animal is sold

56. Which is your main source of farm labour for the dairy farm?

1	0
Household labour *(includes self and other household members)*	***Non Household labour*** *(includes permanently hired and casual labour)*

57. What would you say of your level of satisfaction with your sources of farm labour considering the effects of climate change in your area?

1	2
Satisfied	***Not Satisfied***

58. What plans do you have to improve on the sufficiency of your farm labour so as to increase the productivity of your farm, considering the climate change effects in your area? ***(Please tick all that are mentioned)***

Code	Plan to improve sufficiency of farm labour	Yes (1)	No (2)
1	Hire at peak times		
2	Mechanize production		
3	Supplement with labour from neighbours when schools are closed		
4	Supplement with labour from friends/group of friends at peak times		
5	Supplement with labour from visiting relatives		
6	Supplement with labour from school children (especially over week-ends) in need of pocket money		
7	Reduce number of farm animals		
8	Sell all bull calves to ensure only heifers and cows remain in farm		

59. What has been the trend in your level of income from dairy farming over the past ten (10) years?

1. Increased [ ] 2. Remained same [ ] 3. Declined [ ]

60. Considering the effects of climate change in your area, how satisfied are you with your monthly income from the sale of milk from your dairy cattle?

1. Satisfied [ ] 2. Not Satisfied [ ]

61. Considering the effects of climate change in your area, what would you do to improve the monthly income from dairy enterprise in your farm?***(Tick all that are mentioned).***

Code	Measures to improve monthly income from dairy enterprise	Yes (1)	No (2)
1	Keeping more dairy goats than cows		
2	Going for high yielding breeds of dairy cattle		
3	Going for more crosses of zebu and exotic breeds		
4	Increasing level of intensification (adopting more zero-grazing practices)		
5	Hiring more land for establishment of pasture and other feeds		
6	Buying more land for establishment of pasture and other feeds		
7	Increasing number of exotic breeds in the farm		
8	Improving on management of diseases and parasites in the farm		
9	Improving water source		
10	Improving on fertility management		
11	Improving on housing of dairy cattle in the farm		

Thank you for your participation in this study

Appendix II: KEY INFORMANT INTERVIEW GUIDE FOR HEADS OF GOK, RESEARCH & PARASTATAL UNITS

DETERMINANTS OF ADAPTIVE STRATEGIES TO CLIMATE CHANGE OF SMALLHOLDER DAIRY FARMERS OF MIGORI COUNTY, KENYA
KEY INFORMANT INTERVIEW GUIDE FOR HEADS OF GOVERNMENT (MoALF, MENR & COOPERATIVES), RESEARCH (KALRO) & PARASTATAL UNITS (LBDA, NEMA, & METEOROLOGY)

Informed Consent Page

The principal focus of this discussion is to get your understanding and views regarding climate change and smallholder dairy farming activities in this County.
The information you shall provide will be useful in helping improve smallholder dairy famers' level of understanding, preparedness and coping strategies to climate change effects so as to remain in production; make profits and make significant contributions to Kenya's economic growth and development.
The information you will provide will be treated with utmost confidentiality, and the final report will not bear your name, but only your views, alongside those of others. Participation in this study is purely voluntary, and you are free to withdraw at any point should you find you are unable to continue.
Are you willing to participate in this discussion? Yes [ ] No [ ]
Respondent's Name:_____Designation:_____

I.D. Number:_____Telephone No.:_____
Signature:_____Date:_____

Note: If the respondent declines the interview, thank them for their time and proceed to the next respondent.

Key Informant's Name	
Position/Role	
Office	
Location (Duty Station)	
Place of Interview	
Name of Interviewer	
Name of Note-taker	
Date of Interview	

Interview started:_____**Interview ended:**_____

INTRUCTIONS

- **Introduce yourself and explain the purpose of the study.**
- **Use the questions only as a guide and probe further where necessary.**
- **Seek as much information as possible.**
- **Explain the purpose of voice recorder, and only take note of cues that could remind you of key responses given.**
- **Be involved in the interview and take note of non-verbal communication.**

Interview questions

A. Perception of Climate change in Migori County with respect to temperature

1. Comparing the **temperatures** of Migori County now with those fifteen years ago, what changes would you say have taken place regarding **day** and **night** temperatures? *(Probe for evidenced change)*

B. Perception of Climate change in Migori County with respect to precipitation

2. Comparing the rainfall of Migori County now with that experienced fifteen years ago, what changes would you say have taken place? *(Probe for changes in rainfall seasons, amounts, intensity, distribution, predictability in the onset, and total duration)*

C. Impact of Climate Change on smallholder dairy industry of Migori County and farmers' adaptive strategies

3. How have the changes you have mentioned with respect to temperatures and rainfall affected smallholder dairy farmers of Migori County and how have they responded to the effects in order to remain in business? *(Probe for effect in terms of type of farming practiced, level of intensification of the dairy enterprise, type and choice of breeds of dairy cattle kept, herd dynamics, number of dairy cattle kept, housing for dairy cattle, feeds and feeding of dairy cattle, diseases and parasites affecting dairy cattle, fertility and reproduction of dairy cattle, watering of the dairy cattle, labour type and availability, level of capital investment in dairy enterprise, and milk production and income from milk sales)*

Effect	*Response/adaptation by smallholder dairy farmers*

4. What are the **challenges** (difficulties) facing smallholder dairy farmers of Migori County as they try to adapt to the effects of climate change taking place in this area?

D. Measures to improve Migori County's smallholder dairy farmers' adaptation to climate change effects

5. Based on your knowledge of climate change, mention what the smallholder dairy farmers of Migori County are currently doing, but **should stop doing** in order to sustainably adapt to the effects of climate change.

6. Based on your knowledge of climate change, mention what the smallholder dairy farmers of Migori County **are already doing**, and **should continue doing/could do differently** in order to sustainably adapt to the effects of climate change.

7. Based on your knowledge of climate change, mention what the smallholder dairy farmers of Migori County are **currently not doing,, but should start doing**, which could enable them to adapt better to the effects of climate change.

Thank you for participation in this study!

Appendix III: FOCUS GROUP DISCUSSION GUIDE 1

DETERMINANTS OF ADAPTIVE STRATEGIES TO CLIMATE CHANGE OF SMALLHOLDER DAIRY FARMERS OF MIGORI COUNTY, KENYA

FOCUS GROUP DISCUSSION GUIDE FOR FARMER GROUPS, DAIRY COOPERATIVE SOCIETIES AND ENVIRONMENTAL CONSERVATION GROUPS

Name of group	
Major Group Activity	
Name of Sub-county	
Name of Ward	
Name of Location	
Name of Sub-location	
Name of Village	
Group members present (Females & Males)	
Name of Facilitator/Moderator	
Name of Note take/recorder	
Venue of meeting	
Date	

Discussion begins: _____Discussion ends:_____

As participants arrive thank them warmly for coming, welcome them and put them at ease by friendly conversation. [When the group is complete] Introduce yourself and the note taker and state the use of the voice recorder. Reaffirm from the members that they have come voluntarily to participate in the discussion and that they can still withdraw from the group if they wished to. Seek this consent by a show of hands.

INTRODUCE TOPIC OF DISCUSSION:

The principal focus of this discussion is to get your understanding and views regarding climate change and smallholder dairy farming activities in your community.

The information will be useful in helping improve smallholder dairy famers' level of understanding, preparedness and coping strategies to climate change effects so as to remain in production; make profits and make significant contributions to Kenya's economic growth and development.

The information you will provide will be treated with confidentiality, and the final report will not bear your name, but only your views. Participation in this study is purely voluntary, and you are free to withdraw at any point should you find you are unable to continue.

Ask the group if it is willing to participate in the study. Let it be shown by acclamation.

Group is willing to participate in the study (Tick as appropriate): Yes [ ] No [ ]

Note: If the response is No, please move to the next group.

AGREE ON NORMS AND CONFIDENTIALITY

- Explain the session shall be in form of a discussion
- Stress that there are no right or wrong answers
- Ask participants to feel free to say what they think
- Ask the group to treat what others say as confidential
- Agree on use of cell phone and leaving the room while discussion is in progress etc.
- Tell the discussants how long the discussion will take.

Remind participants this is voluntary and they are free to leave at the start or any time during the discussion.

Discussion questions

A. Perception of Climate change with respect to temperature

1. Comparing now and fifteen years ago, what **changes** would you say have taken place in **day and nighttemperatures** over this area? *(Probe for evidences of noticeable change)*

B. Perception to Climate change with respect to precipitation

2. Comparing now and fifteen years ago, what **changes** have taken place in **rainfall** over this area? (*Probe for changes in rainfall seasons, amounts, intensity, distribution, predictability in onset, and total duration).*

C. Understanding Climate Change effects on Smallholder Dairy Production and adaptation

3. What have been the implications of the observed changes in climate in this area for smallholder dairy farmers, and how have they tried to adapt? (*Probe for implications in terms of survival to maturity of dairy cattle, total quantities and quality of water available for dairy cattle, total amount and variety (type) of feeds (shrubs and herbs) available for dairy cattle, number and types (variety) of diseases and parasites of dairy cattle, fertility and productivity (in terms of calving) of dairy cattle, housing requirements, and milk production and income from milk sales)*

4. What **challenges** (difficulties) do smallholder dairy farmers in your community face as they try to adapt to the effects of climate changes in this area?

5. Suggest **what else could be done** by smallholder dairy farmers in this community to **better adapt** to the effects of changes in climate taking place in this area.

Thank you for participation in this study!

Appendix IV: FOCUS GROUP DISCUSSION GUIDE 2

DETERMINANTS OF ADAPTIVE STRATEGIES TO CLIMATE CHANGE OF SMALLHOLDER DAIRY FARMERS OF MIGORI COUNTY, KENYA

FOCUS GROUP DISCUSSION GUIDE FOR ELDERS (Over 60 Years)

Sub-County:	
Location:	
Sub-Location/Ward	
Village:	
Discussion Venue:	
Group Name (if applicable):	
FGD Participants Present (Total):	
Female:	
Male:	
Facilitator/Moderator:	
Note taker/Recorder:	
Observer:	
Date:	
Time Discussion Started:	
Time Discussion Ended:	

As participants arrive thank them warmly for coming, welcome them and put them at ease by friendly conversation. [When the group is complete] Introduce yourself and the note taker and state the use of the tape recorder. Reaffirm from the members that they have come voluntarily to participate in the discussion and that they can still withdraw from the group if they wished to. Seek this consent by a show of hands.

INTRODUCE TOPIC OF DISCUSSION:

We are here to find out what changes in climate have occurred in your area, how those changes have affected smallholder dairy farmers in your community, and what is being done to remain in business (produce milk and satisfy the demand).

The information will be used to prepare general reports, but will not include any specific names. We can only promise that we shall share our findings with stakeholders in the dairy industry in this County and produce publishable materials that will be read by other people outside this County and this Nation. Participation in the discussion is voluntary and the information you provide will be treated with confidentiality. You are free to withdraw from the study at any point should you find you are unable to continue. For purposes of quality assurance of the information, we request that you allow us to use ***voice recording*** *of this discussion.*

Are you willing to participate in this discussion? Yes [ ] No [ ]

Note: If the response is No, please move to the next group.

AGREE ON NORMS AND CONFIDENTIALITY

- Explain the session shall be in form of a discussion
- Stress that there are no right or wrong answers
- Ask participants to feel free to say what they think
- Ask the group to treat what others say as confidential
- Cell phone use and leaving the room while discussion is in progress etc.
- Tell the discussants how long the discussion will take.

Discussion questions

A. Perception of Climate change with respect to temperatures

1. Using appropriate naturally obtained items (stones, leaves, flowers or twigs), depict on the ground, the changes that have taken place in your community (between **1980, 1990, 2000, 2010** and **now**) regarding the **day** and **night** temperatures.

B. Perception to Climate change with respect to rainfall

2. a) Using appropriate naturally obtained items (stones, leaves, flowers or twigs), depict on the ground, the changes that have taken place in your community (between **1980, 1990, 2000, 2010** and **now**) regarding the following **rainfall amounts** for both the **long** and **short** rainy seasons.

b) Discuss the other changes that have taken place in rainfall regarding seasons, intensity, distribution, predictability in onset and total distribution in the past twenty years in Migori County.

C. Understanding Climate Change effects on Smallholder Dairy Production

3. a) Using appropriate naturally obtained items (stones, leaves, flowers or twigs), depict on the ground, the changes that have taken place (between **1980, 1990, 2000, 2010** and **now**) regarding the **total quantities and quality of water available** for dairy cattle in this community.

b) Using appropriate naturally obtained items (stones, leaves, flowers or twigs), depict on the ground, the changes that have taken place (between **1980, 1990, 2000, 2010** and **now**) regarding the **total amount of milk produced from smallholder dairy enterprise** in this community.

c) Using appropriate naturally obtained items (stones, leaves, flowers or twigs), depict on the ground, the changes that have taken place (between **1980, 1990, 2000, 2010** and **now**) regarding the **average total monthly income from milk sales from smallholder dairy enterprise** in this community.

d) Using appropriate naturally obtained items (stones, leaves, flowers or twigs), depict on the ground, the changes that have taken place (between **1980, 1990, 2000, 2010** and **now**) regarding the **total amount and variety of feeds (shrubs and herbs) available** for dairy cattle in this community.

e) Using appropriate naturally obtained items (stones, leaves, flowers or twigs), depict on the ground, the changes that have taken place (between **1980, 1990, 2000, 2010** and **now**) regarding the **number and types (variety) of diseases and parasites affecting dairy cattle** in this community.

f) Discuss the changes that have occurred in the past twenty years regarding the **survival to maturity of dairy cattle, fertility and productivity (in terms of calving) of the dairy cattle, and housing requirements for dairy cattle** in this community?

D. Adapting to Climate Change Effects

4. How have **smallholder dairy farmers** of this community **tried to adapt** to (i.e. do things differently in response to) the effects of climate change that have taken place in this area over the past fifteen years in order to remain in production? Please explain.

5. What are the **challenges (difficulties)** facing smallholder dairy farmers in your community as they try to adapt to the effects of climate changes in this area?

6. Suggest **what else could be done** by smallholder dairy farmers, the government and other stakeholders to make smallholder dairy farmers of this community **better adapt** to the effects of changes in climate taking place in this area.

Thank you for participation in this study!

APPENDIX V: OBSERVATION GUIDE

DETERMINANTS OF ADAPTIVE STRATEGIES TO CLIMATE CHANGE OF SMALLHOLDER DAIRY FARMERS OF MIGORI COUNTY, KENYA

OBSERVATION GUIDE

AEZ:_____***Sub-County:***_____***Location:***_____

S/Location/Ward:_____***Village:***_____

A.	Observed impact of climate change in the area and efforts to mitigate				
1.	Record observed environmental impacts of climate change in the area at the time of conducting the study (e.g. formation of gullies/ridges, dry river beds, flood basins, conditions of fodder/others) [Please make brief notes about what you observe about each category of impact]	Gullies/ridges	Dry river beds	Flood basins	Condition of fodder/others
2.	Is the community making any efforts to mitigate these observed impacts [Clearly state all observed community efforts to mitigate each impact]				
B.	Observed farming practices, rearing methods, type and numbers of dairy cattle kept				
3.	What farming practices are generally adopted by majority of smallholder dairy farmers in the study area? (Please tick)			Pure dairying	Mixed farming
4.	What rearing method is broadly adopted by smallholder dairy farmers of the study area? (Please tick)		Intensive	Semi-intensive	Free-range

5.	What types of dairy cattle are generally kept by smallholder dairy farmers of the study area? (Please tick)	Pure dairy	Crosses	Mixture of pure dairy & crosses
6.	Which breed is predominant among smallholder dairy farmers in the study area?	Friesians and their crosses	Ayrshires and their crosses	Others (specify)
7.	What is the approximate average number of dairy cattle kept by smallholder dairy farmers of the study area? (Please indicate number)			Number
C.	Others			
8.	Record any other striking observation that may be relevant to the study.			

APPENDIX VI: CHECLIST FOR COLLECTING SECONDARY DATA

DETERMINANTS OF ADAPTIVE STRATEGIES TO CLIMATE CHANGE OF SMALLHOLDER DAIRY FARMERS OF MIGORI COUNTY, KENYA

DOCUMENT REVIEW CHECKLIST

A. Meteorological Department Desk Review-Key questions

1. Assess the available documents for **evidence** of **climate change** in Migori County and its environs over the past **30 years***(Precipitation and Temperature data, both temporal and spatial).*

2. Seek to have a **documentary** understanding of how the evidenced **climate changes** would **manifest***(whether in increased droughts, increased precipitation accompanied by flooding, lightning and thunderstorms, windstorms, landslides, etc.)*

3. Seek for **documentary explanation** for the observed **climate change** [whether changes in pressure belts over some water bodies, hence; wind patterns, global warming, etc.] *(Emphasis on documentary explanation, not verbal, quote source, author and year).*

4. Seek for a **documentary understanding** of the expected **effects** of the observed climate change on the **environment, infrastructure, plants, livestock, livelihoods** and **human lives** (*Emphasis on documentary understanding, not verbal, quote source, author and year).*

B. **Ministry of Environment & Natural Resources/NEMA Desk Review-Key questions** *(To be compared with findings from the Ministry of Agriculture, Livestock & Fisheries)*

1. Assess available documents for **trends** in **flooding** and/or **drought** in Migori County and its environs over the **past 30 years***(Documentary evidence, quoting source, author, and date).*

2. Assess available documents for **effects** of the observed **floods** and/or **drought** in Migori County and its environs on the **environment, infrastructure, plants, livestock**, **livelihoods** and **humans** *(Documentary evidence, quoting source, author, and date).*

3. Establish **evidenced quantification** of the **effects** of observed **floods** and/or **drought** in Migori County and its environs on the **environment, infrastructure, plants, livestock, livelihoods** and **humans***(Documentary evidence, quoting source, author, and date; Seek for numbers of livestock/humans lost; acres of crops and livestock feeds destroyed; kilometres of road/water connectivity destroyed; value (in Kshs.) of crop yield lost, etc.)*

4. Assess **human response** to the **losses** as a result of **floods** and/or **drought** in Migori County and its environs *(Seek to have a documentary understanding of how the locals responded; what external support they received and from who; how timely the support received was; and the result of the external support).*

5. Assess **gaps** in **dealing** with the observed **effects of climate change** (manifesting in floods and/or droughts etc.) in Migori County and its environs *(Documentary evidence, quoting source, author, and date).*

6. Establish **lessons learnt** from the **responses** to **climate change effects** in Migori County and its environs *(Documentary evidence, quoting source, author, and date).*

7. Establish **key recommendations** made by key stakeholders on **how best to deal with the effects of climate change** in Migori County and its environs in future *(Documentary evidence, quoting source, author, and date).*

C. Ministry of Agriculture, Livestock and Fisheries/KALRO

1. Seek to have a documentary understanding of the **impact** of **climate change** in Migori County and its environs on:

a) Water availability for livestock;

b) Availability of feeds (forage) for livestock;

c) The prevalence of livestock diseases and parasites;

d) Milk (and meat) production from cattle (dairy and beef);

e) Calving intervals and calf health.

2. Seek to have a documentary evidence of the **implications** of the **climate change effects** (impact) on **livestock** in Migori County and its environs in terms of:

a) **Type of farming** the farmers opt for (especially the smallholder farmers);

b) The **system of rearing dairy cattle** chosen by smallholder dairy farmers in the County;

c) The **breeds of dairy cattle** chosen by smallholder dairy farmers in the County;

d) The **number of dairy cattle kept** by smallholder dairy farmers in the County;

e) The **labour requirement** for running smallholder dairy farming enterprise in the County;

f) The **choice of feeds** for smallholder dairy enterprise in the County;

g) The **housing requirements** for smallholder dairy enterprise in the County;

h) The **cost of running a smallholder dairy enterprise** in the County.